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WASHINGTON, D. C.

WASHINGTON, D. C., *April*, 1890.

UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

THE PALEOZOIC FISHES

OF

NORTH AMERICA

BY

JOHN STRONG NEWBERRY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1889

[illegible]

CONTENTS.

ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

COLUMBIA COLLEGE, NEW YORK,
February 1, 1889.

SIR: I have the honor to transmit herewith the text and plates of a memoir on the Paleozoic Fishes of North America.

In this I have endeavored to give references to all notices of our older fossil fishes hitherto published, and have added to them descriptions and figures of all such as have come under my observation which have seemed to me to be new to science.

With great respect, your obedient servant,

J. S. NEWBERRY.

Hon. J. W. POWELL,
Director U. S. Geological Survey.

INTRODUCTION.

Although the geology of but a part of the continent of North America has yet been carefully studied, local surveys and general reconnaissances have made known all the principal features of its structure. They have shown that all the members of the geologic series are somewhere in its great area well represented and that the strata contain fossils which enable us to make satisfactory comparisons with the geology of other divisions of the earth's surface, and to fix beyond question the relative position of all important groups of rocks. We have learned, further, that the order of succession in the strata composing the geologic column is the same here as in other parts of the world, and that the progress of animal and plant life during the geologic ages was in North America essentially the same as that revealed by explorations in Europe, Asia, Australia, Africa, and South America.

Here, as elsewhere, the oldest group of fossiliferous rocks is the Cambrian, and it contains a fauna which, including representatives of all the invertebrate subkingdoms, yet consists chiefly of trilobites. These are not only more abundant relatively and absolutely, but are more varied and larger than in the rocks of later ages. Hence the Cambrian is not improperly designated the Age of Trilobites.

In the Ordovician (Lower Silurian) all the invertebrate subkingdoms are well represented, 10,000 or 12,000 species having been already collected from these rocks But the Mollusca are by far the most numerous; and the huge cuttle-fishes, of which the chambered shells known as Orthocerata are sometimes a foot and a half in diameter, were the ruling dynasty.

Hence, from their number, size, and prowess, the Mollusca have given a name to this age, and it is everywhere known as the Age of Mollusks.

Careful search in many countries has failed to discover anywhere in the Ordovician rocks any unmistakable traces of vertebrate life. It is true that the "conodonts," discovered by Pander in the strata underlying St. Petersburg, were considered by him and have been thought by others to be the teeth of cartilaginous fishes, but there is little probability that they are such. I have discussed this question elsewhere[1] at greater length than I can do here, and have shown that they cannot be the teeth of Elasmobranchs. Very diverse opinions have been expressed on the nature of these organs, but Professors Rohon and Zittel have recently (1886) carefully reviewed the entire subject, and have published in the Sitzungsberichte of the Bavarian Academy of Sciences their conclusion, that the "conodonts" are the teeth of annelids. Probably no one now believes that they are the teeth of fishes, and therefore, as the evidence stands, fish life began on the earth in the Silurian (Upper Silurian) age. Even then fishes were very feebly represented in the life of the globe. In the next succeeding age, however, they exhibited enormous development, and their history becomes more and more varied, interesting, and dramatic through the Paleozoic ages. In the Carboniferous and Permian their rule was disputed by the Amphibians, and in the revolution which occurred at the beginning of the Mesozoic the scepter which they held so long passed to the reptiles, and thenceforward they played a subordinate part in the world's history.

The Paleozoic ages, then, formed the culminating period in fish life, when the whole world of waters was theirs, and they expanded rapidly in every direction; early developing a variety of structure and a nice adaptation to their diverse surroundings, which, when fully displayed, can not fail to excite surprise and to be instructive as well as interesting.

In the following pages I shall endeavor to convey some idea of the progress of fish life in North America during their golden age, as illustrated by the large amount of material which has come into my hands.

I have given a historical review of the subject of American Paleozoic fishes in the introduction to my memoir on the fossil fishes of Ohio.[2]

[1] Palæontology of Ohio, vol. 2, 1875, p. 41.

[2] Palæontology of Ohio, vol. 1, 1873, p. 245.

My views on the classification of our older fossil fishes and their relation to living forms are there given at such length, that it has seemed unnecessary to enter on any general discussion of these subjects here. The new material described on the following pages has an important bearing upon some of the questions of a general nature relating to the origin and development of fish life on the earth, and reference will be found to such general questions in the descriptions given of genera and species as they occur in the chronological arrangement which follows, where the fishes of the different geological systems are treated of in order, beginning with the oldest. This review has been carried to the top of the Coal Measures and stops there, as no Permian fishes from this country have come under my observation. I have already prepared a monograph on the fossil fishes of the American Trias,[1] so far as they are known, and almost no Jurassic fishes have yet been found in this country. With the great ichthyic revolution which took place in the Cretaceous age the fishes were brought into much closer relation to those of the present day, and those collected in this country have been made the subject of elaborate and important memoirs by Prof. E. D. Cope, who was specially qualified for this work by his great familiarity with living fishes.

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[1] Mon. U. S. Geol. Survey No. XIV.

PART I.

FISHES OF THE UPPER SILURIAN ROCKS.

FISHES OF THE UPPER SILURIAN ROCKS.

It is known to all geologists that in the Old World a considerable number of fish remains are reported to have been found in the middle and upper portion of the Upper Silurian system. It is true that the ichthyic character of the peculiar organisms here referred to, those named *Pteraspis* and *Scaphaspis* by Huxley and Lankester, has been doubted by many and denied by some, but the authors mentioned are positive in their statements, and there are none among comparative anatomists whose dicta deserve more respect than theirs. We do not yet know whether *Pteraspis* and *Scaphaspis* had under jaws, but if they should prove to have been destitute of these organs, they would be excluded from the class of fishes by some modern zoologists. We know, however, that they were aquatic in habit, fusiform in shape, and for locomotive organs were provided with fins, and that, as in most of the best known fishes of the present and Paleozoic faunas, the body was protected by either plates or scales. Without going further into this mooted question, and leaving to time their assignment to their true places in the animal series, we may at least say that the assemblage of characters which these fossils present is such as to permit us to compare them only with fishes, and should they be excluded from this class, there is no other yet defined into which they could be received. Hence, for the time being at least, it is manifestly wiser to consider them as fishes.

Accepting, then, the verdict of Huxley and Lankester, we may say that fishes *have* been found in the Upper Silurian in the Old World. Until recently it could have been said with truth that they *had not* been found in America. This, however, can no longer be asserted; for Prof. E. W. Claypole has obtained from the middle of the Upper Silurian series in

Pennsylvania the remains of organisms similar to those that had been before discovered in the Ludlow rocks of England. He published[1] a paper on the discovery of Pteraspidian fishes in the Upper Silurian rocks of North America, and in it he describes two species of *Palæaspis*—*P. Americana* and *P. bitruncata*—which he states had been obtained from the Bloomfield sandstone, the upper member of the Onondaga salt group. This would make them somewhat older than any similar fossils found in the Old World.

In addition to these bucklered fishes, Professor Claypole describes in the same paper two minute spines which he considers those of Elasmobranchs. One of these was obtained from the Bloomfield sandstone; the other from a still lower horizon, the Clinton group. These spines are very small, not more than half an inch in length, and broken at both ends; they cannot, therefore, be made the basis of any positive statement or wide generalization. It is perhaps not certain that they are not the spines of crustaceans, such as were obtained by the geologists of New York from the Clinton group in that State and named *Onchus Deweyi*, and at one time supposed to be the defensive organs of fishes. I am, however, disposed to coincide with the view of Professor Claypole, although the ichthyic character of these little objects cannot be asserted until proven by more complete specimens. The question may be definitely settled, however, by the discovery of one spine which shows the proximal extremity. If this should prove to be solid and more or less roughly pointed, we may be quite sure that these are the dorsal spines of fishes; but if irregularly expanded, forming a rim about a central cavity, then we must conclude they were the appendages of crustaceans. The so-called *Onchus Deweyi* from New York has been shown to have belonged to a crustacean, and yet a fragment of the upper end of one of these objects would be naturally taken as a portion of a fish spine.

Special interest attaches to these earliest traces of fishes, and it is to be hoped that those who may have opportunity for continuing Professor Claypole's researches will not fail to improve it, and if possible add to the small but most important group of relics he has described.

[1] Quart. Jour. Geol. Soc. London, 1885, vol. 41, p. 48.

PART II.

FISHES OF THE DEVONIAN AGE.

FISHES OF THE DEVONIAN AGE.

The Devonian system is perhaps better represented in eastern North America than anywhere else, and the rocks of this age form an important part of the splendid Paleozoic section exposed between the Adirondacks and the Pennsylvania line, worked out with so much care by the New York geologists.

The Devonian rocks here form three great natural groups, as follows:

1. Hamilton group	Portage shales.	Huron shale.
	Genesee shale.	
	Tully limestone.	
	Moscow shale.	
	Encrinal limestone.	
	Blue shale.	
	Marcellus shale.	
2. Corniferous group	Corniferous limestone.	
	Onondaga limestone.	
3. Oriskany group	Schoharie grit.	
	Caudagalli grit.	
	Oriskany sandstone.	

By some geologists the Oriskany sandstone is made the summit of the Upper Silurian system, but it was included in the Devonian by the members of the New York survey and by Lyell and Verneuil, who personally examined the New York section, and it certainly forms the natural base of that system. The Oriskany group is a mass of mechanical sediment, which marks a period of physical change, and in places is plainly unconformable with the Upper Silurian strata. In New York the fossils of the Oriskany are different from those of the Silurian below and the Corniferous above, but at De Cewville, Canada, the most characteristic Oriskany fossils, such as *Spirifer arenosus*, *Streptorhynchus hipparionyx*, *Rensselœria ovoides*, etc., are found mingled with Corniferous species and binding the two groups together.

The Devonian age has been called the age of fishes, because all over the world the rocks of this system contain the remains of fishes as their

largest and most characteristic fossils. These were Placoderms, scaled Ganoids, and Elasmobranchs, the first preponderating in number and size, and included some of the most highly specialized, largest, and most formidable of all fishes; for example, *Dinichthys*, a gigantic *Coccosteus*, was perhaps fifteen feet in length, encased in armor, and provided with formidable jaws, which would have severed the body of a man as easily as he bites off a radish. The scaled Ganoids included both the rhombiferous and cycliferous varieties, and varied in size from the club-like *Palæoniscus* to the cycliferous Crossopterygian *Onychodus*, eight or ten feet in length. The Elasmobranchs were represented by Sharks and Chimæras, but these were far less numerous than in the succeeding age.

The bone beds of the Corniferous limestone, in which the remains of millions of marine fishes of middle Devonian age are strewed over the old sea bottom, contain numerous stud-like, often highly ornamented, dermal tubercles, and occasionally fragments of the pectoral spines of *Machæracanthus*, but almost no teeth of cartilaginous fishes. Many teeth of *Onychodus* are there, often broken and sometimes worn, as though having suffered trituration; but the limestone in which they lie was deposited in comparatively deep and still water, and they could only have been broken and worn by violence or the digestive energy of the fishes which swallowed them. These bone beds contrast strongly with those of the Carboniferous limestone, where the fish remains are nearly all of Sharks, and show that somehow during the interval between the central epochs of these two ages the fish life of the sea was completely revolutionized, the powerful Placoderms having yielded the scepter to the Sharks, for which the Carboniferous was the golden age.

In the Upper Devonian (Hamilton period), when the sea from which the Corniferous limestone was deposited had become shallowed and its sediments were more carbonaceous and earthy, Sharks were apparently more numerous than before, as we find the dorsal spines of several species of *Ctenacanthus* and the teeth of *Cladodus*, which doubtless belonged with them, and yet the Placoderms are also numerous and large. *Onychodus* survives from the Corniferous period, but in a new and peculiarly modified species (*O. Ortoni* N.), in which the large median teeth of the lower jaw were planted in the arch of bone which bore them instead of being set astride of it. Little

tile-scaled Ganoids, allied to *Palæoniscus*, were there, and served as food for the larger ones, as we learn from their scales and bones in coprolites, but no entire individuals have yet been found.

In Canada a most interesting fish fauna has been discovered in the Upper Devonian rocks, and many genera and species have been described by Mr. Whiteaves, the palæontologist of the Canadian Geological Survey. These fishes are generally small, are closely allied to, and in some instances perhaps identical with, the fishes of the Upper Old Red Sandstone of Scotland, and, like them, were apparently the inhabitants of fresh water.

ORIGIN OF THE DEVONIAN FISHES.

The derivation of this fish fauna is unknown to us. The Devonian Cephalaspidians, *Cephalaspis*, *Acanthaspis* and *Acantholepis*, have affinities with *Pteraspis* and *Scaphaspis* of the Upper Silurian and are perhaps their descendants, but the origin of the most striking and characteristic elements in this fauna—the gigantic *Dinichthidæ* and the scaled and plated Ganoids, *Onychodus*, *Macropetalichthys*, and *Asterosteus*, as also the great Pterichthid *Aspidichthys*, and the Elasmobranchs *Rhynchodus* and *Machæracanthus*, among the largest and most highly specialized of all fishes—will perhaps always remain a mystery. Most of these were inhabitants of the Corniferous sea, and came in from the great oceanic basins with the flood which at a certain time inundated parts of the North American continent and deposited upon them the sediments which we call the Lower and Middle Devonian rocks. Presenting, as these fishes do, extreme forms of development in different directions, they must have had a long term of existence previous to their appearance in the Devonian sea, but up to the present time we have discovered no evidences of their derivation from other invertebrate or vertebrate organisms, and no traces of the training schools in which they were brought to such diversified perfection according to their different plans of structure.

STRATIGRAPHICAL DISTRIBUTION OF DEVONIAN FISHES.

Neither in New York nor farther south has the Oriskany sandstone yet furnished any remains of fishes, but it is to be expected that when sought for patiently and discriminatingly they will be discovered. In Canada,

north of Lake Erie, where the characteristic fossils of the New York Oriskany are associated with those of the Corniferous limestone, spines of *Machæracanthus* and fragments of plates with a stellate tuberculation, probably of *Macropetalichthys*, have been found.

The Caudagalli grit occurs only over a limited area in eastern New York, and is a local exhibition of the passage from the coarser Oriskany sandstone to the calcareous beds above. So far it has yielded only one fossil, the sea-weed *Spirophyton*, but it is almost certain that careful search in it will bring to light other things.

The Schoharie grit is only a local siliceous phase of the basal portion of the Corniferous limestone, deposited in some off-shore locality where sometimes half the mass was land-wash. Its fossils are essentially the same as those of the Corniferous limestone, and the remains of fishes are not unfrequently found in it. Among these I have seen some fragments that belonged to species which are certainly new, but they hardly suffice for satisfactory description. The remains of two yet undescribed fishes have been recently sent to me from Schoharie, N. Y., by Mr. W. G. Gebhard; one a Placoderm, with tuberculated Plates; of the other I have only a portion of a bone, apparently belonging to the shoulder girdle, and of which the exposed surface is closely set with large, rounded, smooth tubercles, resembling those of *Aspidichthys* and it may possibly have belonged to a fish of that genus.

SECTION A.—FISHES OF THE CORNIFEROUS LIMESTONE.

The Corniferous limestone was the open-sea deposit of the Devonian age; having several lines of outcrop extending from Canada to Tennessee and being quarried in many localities for lime and building stone, its fossils are as well known as those of any other element in the geologic column. In the State of New York the Corniferous limestone, including the Onondaga, is perhaps sixty feet in thickness. It contains there considerable bituminous and some earthy matter, but is mainly carbonate of lime. In Ohio it is thicker, and contains much more magnesia. About the line of the Cumberland River in Kentucky it runs out, showing that the basin in which it was deposited did not extend farther to the southeast, but it com-

municated freely with the ocean toward the southwest, though it was nearly inclosed by land, viz, a line of islands along the Cincinnati arch and the Canadian and Alleghany highlands.

The remains of fishes in the Corniferous limestone early attracted attention. Mr. Joseph Sullivant, of Columbus, Ohio, was probably the first to notice and collect them, but he did not attempt to describe them. As early as 1836 he presented a cranium, which he obtained in his quarries at Columbus, to Marietta College, Ohio, and I subsequently made this the type of *Macropetalichthys Sullivanti* as a recognition of the value of his contributions to geology.

In 1846 Dr. D. D. Owen and Dr. J. G. Norwood published[1] a description of a new fossil fish from the Paleozoic rocks of Indiana. This fossil was very badly preserved and has since been lost, but there is no doubt it was generically identical with one of the best known of our Corniferous fishes, and therefore that the name *Macropetalichthys* then given must stand.

Somewhat later Dr. R. P. Mann, of Milford, Ohio, became much interested in the remains of fishes in the Corniferous limestone, and made a fine collection of them, which he presented to the Wesleyan University, at Delaware, Ohio. Quite a number of these, with others, sent to me by Prof. F. Merrick, of Delaware, and Dr. E. S. Lane, of Sandusky, Ohio, were described in a paper read before the National Institute, Washington, January 26, 1857.

In 1855 Prof. William Hopkins figured and described,[2] but did not name, a spine from the Corniferous limestone of New York. This fossil was subsequently taken as the type of the genus *Machæracanthus*, and was shown to be the pectoral spine of a shark.

The fossil fishes of the Corniferous limestone have been further described by the writer in the following papers: Annals of Science, vol. 1 (1853); Proc. Amer. Assoc., 1853, p. 166; Bull. National Inst., 1857, p. 19; Am. Jour. Sci., vol. 34, 1862, p. 73; Pal. Ohio, vol. 1, p. 247; vol. 2, p. 1.

[1] Am. Jour. Sci., 2d series, vol. 1, 1846, p. 367.
[2] Proc. Am. Assoc. Adv. Sci., 8th (Washington) meeting (1855), p. 287.

In the paper read before the National Institute in 1857 on the Fossil Fishes of the Devonian Rocks of Ohio the following species were described:

DEVONIAN FISHES.

Macropetalichthys Manni, Newb.
Macropetalichthys Sullivanti, Newb.
Onychodus Hopkinsii, Newb.
Onychodus sigmoides, Newb.
Psammodus antiquus, Newb.
Machæracanthus major, Newb.
Machæracanthus peracutus, Newb.
Machæracanthus sulcatus, Newb.
Oracanthus fragilis, Newb.
Oracanthus granulatus, Newb.
Oracanthus multiseriatus, Newb.
Oracanthus abbreviatus, Newb.

Of these, *Macropetalichthys Manni* is perhaps only the young or a sexual variety of *M. Sullivanti*. *Onychodus Hopkinsii* is erroneously included in the list, as it is confined to the Chemung rocks, and will be noticed further on. Of the species of *Oracanthus* enumerated, perhaps none belong to the same genus with its type, *Oracanthus Milleri* of Agassiz, but they are more likely to prove to be some of the singularly varied spine-plates of *Acantholepis*.

Combining all the notices of the fossil fishes of the Corniferous limestone published up to the present time, we have the following lists of species:

ELASMOBRANCHS.

Machæracanthus major, Newb.
Machæracanthus sulcatus, Newb.
Machæracanthus peracutus, Newb.
Rhynchodus frangens, Newb.
Rhynchodus secans, Newb.
Rhynchodus crassus, Newb.
Oracanthus (?) *fragilis*, Newb.
Oracanthus (?) *abbreviatus*, Newb.
Oracanthus (?) *granulatus*, Newb.
Psammodus antiquus, Newb.
Cyrtacanthus dentatus, Newb.

GANOIDS.

Macropetalichthys Sullivanti, Newb.
Macropetalichthys Manni, Newb.
Macropetalichthys rapheidolabis, N. & O.
Onychodus sigmoides, Newb.
Asterosteus stenocephalus, Newb.
Acanthaspis armatus, Newb.
Acantholepis pustulosus, Newb.
Liognathus spatulatus, Newb.
Coccosteus occidentalis, Newb.

Of the species mentioned in the above list those of the genus *Machæracanthus* are the pectoral spines of Sharks, of which we have no other known remains. They are not uncommon in the Corniferous limestone of Canada, New York, and Ohio. The largest are sometimes a foot and a half in length, are composed of extremely dense tissue covered with polished enamel, and are sharp at the point and on the edges; the surface slopes from a central ridge to the margin on either side, and this slope is concave like those of a bayonet, apparently for the same reason, viz, to gain the greatest strength

with the least material. It is an important fact that spines belonging to the genus *Machæracanthus* and possibly to the species *M. major* have been found in the Devonian limestones of Bohemia and in the Hartz Mountains, and are described by Barrande[1] under the name of *Ctenacanthus Bohemicus.*

The teeth to which I have given the name of *Rhynchodus* constitute a remarkable and interesting element in the fish fauna of the Corniferous limestone. There can be no reasonable doubt that they belonged to Chimæroids, and as they are numerous and exhibit considerable diversity of structure, they show that this group of fishes, now almost extinct, had its golden age far back in geological time. In some cases four teeth with pointed and upturned extremities formed a beak not unlike that of turtles and some birds; a structure that suggested the name given to the genus. In the largest species, *R. frangens,* which was much like and nearly as large as *Chimæra Townsendii,* from the Jurassic, the upper edge formed a broad triturating surface. In another species, *R. secans,* the edges were sharp, and played on each other precisely as did the dental plates of *Dinichthys Terrelli.* In one specimen which I have four are lying together approximately in their original positions. I have sometimes called these beak-teeth mandibular, from their resemblance to the mandibles of birds, though aware that only half of them belonged to the lower jaw.

Psammodus antiquus is notable, because, so far as known, it is the pioneer of the great group of pavement-toothed sharks of the Carboniferous age.

The very peculiar spine, which I have called *Cyrtacanthus,* will probably be found to be only one branch of a fork, and perhaps not generically distinct from Agassiz's *Cladacanthus;* but if so, it will be the first Devonian species known, all others being of Carboniferous age.

FISH BEDS OF THE CORNIFEROUS LIMESTONE.

In the report of the Geological Survey of Ohio I have referred to two genuine fish beds in the Corniferous limestone of Ohio and Indiana. Although they have furnished no complete fishes and few entire plates or teeth, they are of special importance, as they give us a better view of the fish life

[1] Dr. E. Kayser, Die Fauna der ältesten Devon-Ablagerungen des Harzes, Abhandl. Geol. Specialkarte preuss., etc., 1878, vol. 2, Heft 4, p. 3; Atlas, pl. 35, fig. 12.

of the Devonian sea than we are able to get from isolated specimens however perfect; they therefore deserve a few words of description.

The first of these bone beds was discovered by Mr. J. H. Klippart, in the upper part of the Corniferous limestone, a few miles north of Columbus, Ohio. The stratum in question is only from two to four inches in thickness, but it extends over an area of many square miles. It is almost entirely composed of fragments of plates, teeth, spines, and dermal tubercles of Ganoids, Placoderms, and Elasmobranch fishes. Unfortunately most of them are so much broken and worn, that they are difficult and disappointing objects of study; but the deposit is one of peculiar interest from its mode of formation and from the comprehensive view it gives of the Devonian fish fauna.

Here we have the assemblage of millions on millions of generally imperfect but mostly recognizable organs or fragments of the bony structure of the forms of fish life most characteristic of the Devonian age. There are many entire teeth and dermal tubercles, but these are always detached and scattered. Most of the fragments are worn and rounded, and have evidently been subjected to some sort of triturating agency. They have the aspect of having been beach-worn, but the mass is almost entirely organic, and it is difficult to understand how it could have accumulated along a shore line without some intermingling of sand or pebbles. It forms a thin layer in a thick sheet of organic sediment, which must have been deposited in comparatively deep water, for no land wash of any kind is associated with it. It has seemed to me not impossible that this fish bed was for the most part made up of excrementitious matter, and that it represents the hard and indigestible parts of fishes which have served as food for other and larger kinds. On this supposition the fragmentary and worn appearance of the bones would be attributable to the crushing, maceration, and partial digestion which they have suffered. If this is the true history of the deposit, it accumulated in some nook or bay, perhaps bordering a coral reef, where large and small fishes congregated age after age until their "kjokkenmöddings" formed a sheet some inches in thickness over all the sea bottom. By whatever process accumulated, this mass of fish remains constitutes a most remarkable deposit, and one not less interesting as a geological formation than because of the many forms of ancient life it contains.

A fish-bed not unlike this occurs in the Corniferous limestone at North Vernon, Ind. The two deposits correspond closely in geological position and character, and many of the fossils are the same in both, so that we must conclude they have had a similar history. Among the fossils of the Columbus fish bed there are thousands of the teeth of *Onychodus*, with fragments of the head plates of this genus and of *Macropetalichthys;* the latter recognizable by their peculiar tuberculation. The spines of *Machæracanthus* and *Acanthaspis* also occur there, but by far the most numerous of the fossils contained in the deposit are the stud-like dermal ossicles of Selachians Of these most are plain, but some have the exposed surfaces ornamented with radiating ridges, like a scallop shell, and closely resemble those described by C. H. Pander[1] under the name of *Cœlolepis* and *Nostolepis.* Associated with these are numerous Elasmobranch teeth, generally of small size and showing considerable diversity of form, but most of them would probably come into the genus *Chomatodus* of Agassiz.

The abundance of the remains of Elasmobranch fishes in this deposit is surprising, considering their general scarcity in the Corniferous limestone, and indeed in all the Devonian rocks It should be said, however, that even here the relics of Sharks are, with the exception of the spines of *Machæracanthus*, all small, and we find nothing which requires important qualification of the view advanced in the Palæontology of Ohio, viz, that "in the Devonian seas the Elasmobranchs were comparatively few and small, and they were far surpassed in numbers and in size by the scaled and plated Ganoids, which constituted the summit of the zoologic series and the ruling dynasty at that age of the world."

The fish-beds described above deserve more careful consideration than they have yet received, and it is to be hoped that some one who is favorably located will make them the objects of careful and prolonged study. In no other way can the immense mass of animal remains they include be properly investigated, and it is quite certain that the results would justify the devotion of considerable time to the task. Both the deposits are veritable cemeteries; they extend over considerable areas and are very accessible. Probably all the fishes that lived in the waters from which the Cor-

[1] Monographie der foss. Fische des silurischen Systems, p. 65, Pl. 4, Fig. 13.

niferous limestone was deposited have left here some traces of their existence, and with proper study a catalogue, which should have a reasonable degree of completeness, could be made out of the fish fauna of the basin that in the Devonian age occupied the area between the Cincinnati arch, the Alleghany belt, and the Canadian highlands. Isolated specimens found elsewhere would supply anatomical details and serve for the reconstruction of entire individuals and thus of genera and species, but nowhere else, so far as my knowledge extends, can we get such a comprehensive view of the ichthyic fauna of the age.

Order PLACODERMI.

Family CEPHALASPIDÆ.

Genus ACANTHOLEPIS, Newb.

Among the fish remains found in the Corniferous limestone are many tuberculated cranial or dermal plates which have a prevailing spatulate outline, but differing much among themselves in form and consistence. Some are thin, and have the appearance of large, unsymmetrical scales; others are thicker, and are produced into points that sometimes become spines. The outer surface of all these plates is more or less tuberculated; the tubercles in some of them being strong and closely crowded, in others sparse and fine. Whether these are body scutes or cranial plates remains to be shown by future discoveries. That they form part of a somewhat extended series which compose a more or less complete coat of armor is shown by the fact that in some instances two or more are found in close contact and occupying their true positions as regards each other. The fishes that bore these defenses were evidently of large size, as the scutes which formed their tessellated armor are sometimes eight or ten inches in length by two inches in width. Other plates are smaller, elliptical, spatulate, or triangular in outline, and several forms have angles which are produced into spines.

Until more material shall be obtained which may serve for the reconstruction of this remarkable fish it would be premature to make any positive assertion in regard to its zoological relations. I may say, however, that judging from the specimens before me, *Acantholepis* was a Placoderm, having *Acanthaspis* as its nearest ally in the Corniferous sea; both presenting characters which indicate an intimate relationship with *Cephalaspis.*

In a paper published some years since in the Bulletin of the National Institute at Washington, I described a number of fish remains obtained at Delaware, Ohio, by the late Dr. Mann. Among these three species of *Oracanthus* were described, viz, *O. fragilis*, *O. granulatus*, and *O. abbreviatus*, all of which I now believe to be phases of the varied scutes of *Acantholepis.* Some

of the triangular ones seem to have resembled in form and functions the dermal spines of *Climatius, Parexus,* etc., and it is possible that they were set in greater or less number on the body. Some are quite spine-like in character, narrow, compressed and acute, but toward the bases of the cones they form the walls are crushed together, and it is evident that they were thin, bony, and enameled shells attached to the surface of the body or head, where composed of soft tissues, and were not planted in the integuments like the spines of Elasmobranchs. There is probably much heterogeneous material included in the genus *Oracanthus,* for some of the spines assigned to it are solid, symmetrical, roughened, and pointed at the base, and are plainly the dorsal spines of Sharks; others are unsymmetrical, the sides being of unequal breadth, and these, I suspect, were the pectoral spines of Elasmobranch fishes.

Mr. J. W. Davis, in his work on the fishes of the Mountain limestone, recognizes their paired character, but locates them back on the body. Dr. Traquair suggests that a spine of this kind, which he has called *Oracanthus armigerus,* was the defense of the angle of the head. This seems highly probable, and it may be true of the triangular spines of *Acantholepis* as well as of the spines called by St. John and Worthen *Pnigeacanthus.*

Acantholepis pustulosus.

Plate XXXI, Figs. 5, 5^a, 5^b.

Cranial or body scutes having a somewhat spatulate form, and attaining in some cases a length of seven or eight inches and a breadth of two inches. These scutes were set contiguous to each other, forming a defense to the body or head; the more elongated ones becoming curved spines, similar in general character to those of *Acanthaspis,* but differing in this, that they are not united by sutures with flat bones or plates, but are the extremities of such plates drawn out into spines, which must have projected from the general surface. The broader plates are quite thin, and seem to have been applied to flat or arched surfaces, while those which form spines have their remote extremities narrowed and thickened till they become prominent and effective defensive organs. In some instances the plates are triangular in

outline, and seem to have been thin cones of bone or enamel, supported by cartilaginous centers. As the latter are decomposed, the sides, which were once widely separated, were brought together or crushed in like broken shells.

The external surface of these plates is tuberculated in a variety of ways. In some instances the tubercles are large, scattered, smooth and rounded, and resemble pustules. In other cases they are irregular and crowded; while occasionally they are in rows, the interstices between them being beautifully chased and ornamented. Along the margins of the spinous extremities of the plates the tubercles are elongated until they become conical denticles.

On Pl. XXXI, Figs. 5, 5^a represent a large pair of plates in their relative positions; Fig. 5^b, two such pairs. A number of groups of this kind have been found, though the individual plates are oftener met with entirely separated from their connections. The extremity of Fig. 5 is not quite complete. Other specimens show that it was produced to a moderately acute flattened point. This narrow end was beautifully denticulated, was tuberculated on both sides, and evidently projected from the body or head as a defensive spine.

Formation and locality: Corniferous limestone; Delaware, and Sandusky, Ohio.

Genus ACANTHASPIS, Newb.

This name is used to designate certain cranial bones of what seems to have been a Cephalaspid, found in the Corniferous limestone of Ohio. Considerable variety is noticeable in the shape of these plates, and it is apparent that they formed parts of a tessellated cranium. They are generally somewhat oblong in form, the greater part of the plate being quadrangular, while one of the margins is oblique and prolonged into an acute point, and to this margin is spliced a carinated, toothed spine, sometimes four or five inches in length. These spines bear considerable resemblance to the dorsal defenses of some extinct Sharks. They might, indeed, under some circumstances be accepted as the spines of *Ctenacanthus*, since they are marked with pectinated ribs much in the same way, but their attachment to bony plates and the

denticulation of both sides of the pointed extremity show distinctly that they have only a superficial resemblance to the defensive spines of Elasmobranch fishes. When complete and seen in position they reveal their affinities with the lateral cornua of the cephalic buckler of *Cephalaspis.* The external surface of the plates to which these spines are attached is marked with a conspicuous and peculiar ornamentation, much like that of *Bothriolepis;* a series of convoluted, locally parallel, raised and beaded lines. As the central plates of *Acanthaspis* have never been found in connection, it is impossible to give at present the form of the cranium, but they are seen to be in pairs, and it is highly probable that when united they formed a rounded head-buckler, which differed from that of *Cephalaspis* mainly in being composed of a series of separable plates, instead of forming a solid box.

Acanthaspis armatus Newb.

Plate XXX, Figs. 1–4.

Cranium consisting of a number of bony plates, forming several pairs, and differing considerably in outline. To at least one of these pairs are attached, on the outer margin, strong, slightly curved, carinated, tuberculated and toothed spines. The external surface of the plates is covered with convoluted or radiated raised lines, which are more or less tuberculated.

Several cranial plates of this species are represented in the figures now published, and these will give a better idea of their form and markings than any verbal description can do. These plates, and the spines which are connected with some of them, are frequently met with in the Corniferous limestone of Sandusky and Delaware, Ohio, but like the cranial plates of *Onychodus*, they seem to have had no bony attachment to each other, and in the dissolution of the body of the fish which bore them they have been widely separated. There is little doubt that sooner or later some cranium will be found in which the bones hold their normal positions, and from such a specimen a more complete description of the fish can be drawn than can now be given. Waiting the discovery of such complete material, the plates now

figured will doubtless be looked upon with interest, and will stimulate the search for more remains of what has till recently been an entirely unknown Devonian fish.

Order ELASMOBRANCHII.

Genus MACHÆRACANTHUS, Newb.

Spines often of large size, curved, ancipital, unsymmetrical (dextral and sinistral); edges and point generally acute; base somewhat narrowed, with a rough and irregular extremity; central cavity reaching nearly to the apex; external surface covered with a thin coating of enamel, in some species smooth, in others punctate and longitudinally striated; microscopic structure that of dense, ivory-like bone.

These spines are very characteristic of the horizon of the Corniferous limestone, having been found at this level in Indiana, various localities in Ohio, in New York, and at Gaspé, Canada. Though representing some anomalous characters, among which the most remarkable is their want of symmetry (being rights and lefts), it is hardly possible they can be anything else than the defensive spines of fishes. Their dense, bony structure, enameled surface, and rough irregular bases would seem to prove that, like the fin spines of many Sharks and Rays, they had been implanted in the integuments without articulation. Probably they were the first rays of the pectoral fins, which would account for their being in pairs. In that case it might be expected that the bases would exhibit some marks of their articulation to the pectoral arch; but as the fishes which bore them were undoubtedly cartilaginous, the insertion of pectoral spines—supposing they possessed them—would naturally somewhat resemble that of the dorsal spines. Many bony fishes, as *Arius*, etc., bear formidable dorsal and pectoral spines, but these always exhibit some indications of an articulation at their proximal extremities. In the Sharks, Chimæras, and Rays, however, the dorsal spines are simply implanted in the integuments of the back, and each spine has a roughened and attenuated base, which is surrounded by a larger or smaller mass of cartilage.

Comparatively few cartilaginous fishes of the present epoch are provided with even dorsal spines; and none, so far as known, carry spines on the pectoral fins. But in the Mesozoic and the Paleozoic ages the Elasmobranch fishes were much more generally provided with spines, and it is not too much to suppose that this tendency to the development of organs of defense should be exhibited in spines appended to the anterio paired fins. We have, in fact, positive evidence that some of the sharks of the Carboniferous age did carry pectoral spines.

Several of the species of *Gyracanthus*, for example, are now generally conceded to have been pectoral spines. This is shown by their want of symmetry, which proves that they were not set on the median line, and by the fact that they are worn off in various degrees, as though used as organs of locomotion on the sea bottom or shore. A series of spines of *Gyracanthus formosus*, in the cabinet of Columbia College, show, (1) a slender, complete, evidently young spine ten inches long and unworn; (2) a large spine nine inches long, of which the summit is obliquely and smoothly worn off where five-eighths of an inch in diameter; (3) the base of an old and very large spine worn away nearly to the end of the ornamented portion.

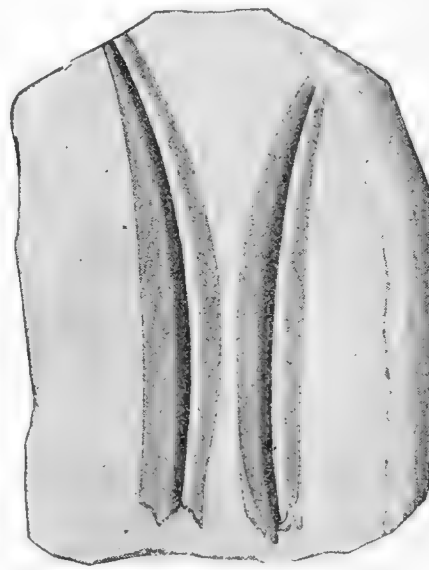

FIG. 1. Spines of Machaeracanthus peracutus.

I have also shown in another part of this memoir that the spines called *Physonemus Altonensis* by St. John and Worthen were certainly appendages to the pectoral fins. This was first suspected from their obvious want of symmetry, and was finally proved by finding complete specimens buried in soft shale, in which the cleft of the convex margin is occupied by the base of a broad pectoral fin.

The accompanying wood-cut, copied from my notes[1] on *Machæracanthus*, is an imperfect representation of a very interesting specimen found by Professor Hopkins in the Corniferous limestone near Auburn, N. Y. This represents a pair of spines of *Machæracanthus peracutus* which occupy nearly the relative position they would hold if they were connected with the pectoral fins, and these had been brought near together. The fact of finding *such a pair* of spines in such relations practically demonstrates that they were connected with the paired fins.

As I have remarked elsewhere, *Machæracanthus* occurs in the Devonian limestones of Europe as well as in America, and Barrande's so-called *Ctenacanthus Bohemicus* is nothing else than a species of *Machæracanthus* closely allied to our *M. major*.[2]

Machæracanthus major Newb.

Plate XXIX, Figs. 4, 4a.

Machæracanthus major N.; Bull. Nat. Inst., 1857, p. 6.
Palæontology of Ohio, vol. 1, p. 304, Pl. XXV, Fig. 2.

Spine large and strong, length twelve to twenty inches; greatest breadth one and a half inches; wing of concave border widest; point moderately acute; base narrowed and compressed, with a rough and irregular termination; upper surface lightly striated longitudinally, central axis projecting in an imperfectly rounded ridge, one-half an inch wide, elevated three-tenths of an inch above the wings; under surface of central axis marked by about ten distinct longitudinal carinations; axis five-eighths of an inch wide, flattened, obliquely angled at sides, rising one-quarter of an inch above the wings; base unequally sloped off where it was set obliquely into the integuments. At this point the carinations of the upper part become obsolete; sides of axis above and below punctate.

Formation and locality: Corniferous limestone; Columbus, Delaware, and Sandusky, Ohio.

[1] Palæontology of Ohio, vol. 1, p. 303.

[2] See A. Roemer, Beiträge, p. 26, Pl. IX, and Kayser, Die Fauna der ältesten Devon-Ablagerungen des Harzes, Abhandl., etc., vol. 2, Heft 4, p. 4; Atlas, Pl. XXXV, Fig. 12.

MACHÆRACANTHUS PERACUTUS Newb.

Plate XXIX, Figs. 6, 6[a].

Machæracanthus peracutus N.; Bull. Nat. Inst., loc. cit.
Palæontology of Ohio, vol. 1, p. 305, Pl. XXIX, Fig. 6.

Spines five to six inches in length, seven to eight lines wide; point and edges very sharp; wings nearly equal; central axis on the upper surface forming a sharp and narrow carination, below a higher but more rounded ridge.

This is perhaps the species most common in Ohio. It will be recognized by its small size, the acuteness of its point and edges, and by the angular ridge of the median line above and below. It is the species referred to in the generic description and that which furnished the figures employed there to show the paired character of these spines. The average size and appearance are well shown in the illustration cited above.

Formation and locality: Corniferous limestone; Delaware and Sandusky, Ohio.

MACHÆRACANTHUS SULCATUS Newb.

Plate XXIX, Figs. 5, 5[a].

Machæracanthus sulcatus, N.; Bull. Nat. Inst., loc. cit.
Palæontology of Ohio, vol. 1, p. 305.

Spine four to eight inches in length, six to ten lines wide; upper surface smooth, with a strong and sharp carination along the axis; wing of convex side widest; opposite wing narrow, and exhibiting a strong marginal sulcus, giving it a double edge; under surface of axis rounded, with several longitudinal sulci and carinæ and with oblique angles at sides.

At the time of writing the description of this species I had no sufficiently good specimen to furnish a satisfactory figure. Since then I have, however, found better specimens in the collection of the late Dr. Mann, now belonging to the Ohio Wesleyan University at Delaware, Ohio, and a number of more or less well-preserved spines have been sent to me for examination from Canada. It would seem that the sharks that carried these spines were more numerous in those portions of the Corniferous sea which covered

western New York and southern Canada than in the more open waters of the area now occupied by Ohio. In the exposures of the Corniferous limestone on Kelley's Island, Lake Erie, at Sandusky, Delaware, and Columbus, Ohio, fragments or complete spines of *Machœracanthus major* and *M. peracutus* are not at all uncommon, but though collecting extensively myself in those localities I never obtained there a specimen of *M. sulcatus.*

As will be seen by the section which accompanies the figure now published, the spines of this species were much narrower and more stiletto-like than the others, which rather suggest bayonets, and afford an interesting illustration of the device that gives strength with economy of material, viz, a prominent carina along the middle, with concave slopes to the acute edges.

A fairly good figure of this spine was given, without a name, by Prof. James Hall, in the Geology of New York, part 4, page 174, and a reduced copy of Professor Hall's figure is published in Dana's Manual of Geology.

The spines of *M. sulcatus* are frequently, perhaps generally, twisted, as the pectoral spines of *Gyracanthus formosus* are.

Formation and locality: Corniferous limestone; Milford, Ohio, and many places in New York and Canada.

Order GANOIDEI.

Suborder CHONDROSTEIDÆ.

Genus MACROPETALICHTHYS, N. & O.

I have elsewhere[1] defined this genus, and have reviewed its characters and relations to other fishes, living and fossil, at such length that it will not be necessary to go over the subject again in detail. The generic description given by Drs. Norwood and Owen was very defective from the imperfections of the specimen which served as a type. The essential generic characters may be briefly given as follows:

Ganoid fishes of large size; cranium composed of large polygonal plates united by double sutures, which are nearly concealed by the tubercled enameled surface; tuberculation stellate, surface ornamented by double rows of pores and single-thread

[1] Palæontology of Ohio, vol. 1, p. 290.

lines, forming a pattern which does not correspond with the plates below; eye orbits conspicuous, inclosed in the orbital (frontal ?) plates; nasal plate (ethmoid ?) wedge-shaped, the apex turned backward, and reaching to the center of the cranium; occipital plate (supra-occipital) oblong, emarginate behind, prolonged anteriorly into a point, which meets the opposing point of the nasal plate; teeth and scales unknown, probably wanting.

Since the publication of the above description numerous heads of *Macropetalichthys* have been found at different places in the Corniferous limestone, and two of these which I have examined show the under surface. This is in a general way flat and smooth, but is marked by a transverse furrow, which probably indicates the position of the mouth. No jaws or teeth are visible, and it is almost certain that fishes of this genus had no bony jaws or teeth; otherwise they would long since have been discovered. It seems probable, therefore, that the mouth of *Macropetalichthys* was like that of the sturgeons, with which I am inclined to associate it, soft and suctorial. Whether there were rudimentary jaws like those of *Acipenser* attached to the head of *Macropetalichthys* we cannot say, but it is quite possible. Yet, even if jaws were wanting, that would seem to me no good reason why this should not be considered a fish and a member of the order *Chondrosteidæ.*

Professor Hæckel has made the possession of an under jaw a condition of the acceptance of any organism as a member of the class of fishes; but this seems to me to be unphilosophical and unwarranted. No one can say to what limits the atrophy, by modification or disuse, of any single organ among the vertebrates may be carried. Perhaps nine-tenths of the organs might remain distinguishable and even normal while one perished, and it is a short-sighted philosophy which would classify the animal kingdom by a rule so narrow. A wing is generally regarded as a characteristic and essential organ in a bird, but we know that in *Apteryx* and *Dinornis* the wings are practically obsolete, and yet no one would dare to exclude these from the class of birds. *Macropetalichthys* was evidently a large and doubtless normal member of the great group of fishes which led and gave character to the life of the Devonian age. As I have elsewhere urged, it was undoubtedly a fish, and probably an ancestral form of the sturgeons of to-day. Indeed, it has been a matter of surprise to me to find that it represented so well the

essential characters of the sturgeons. The number and size of the body-scutes of the sturgeons vary much. In *Scaphirhynchus* they are nearly contiguous; in *Polyodon* they are absent; and of the sturgeons with few or no scutes nothing but the cranium would be likely to be preserved in fossilization. I have often found on the beaches of islands in Lake Erie the remains of sturgeons thrown up by the waves. These usually consist of scattered dermal scutes and the brain-box; often the cranium alone was found, a hollow shell of bone, from which all the appendages of the under side and interior had been removed by decay. The resemblance of such an object to the cranium of *Macropetalichthys* is striking, and when we compare the cranial plates of both, there seems to be as close correspondence as we often find between living and fossil fishes. I give below a diagram of the cranial plates of *Macropetalichthys* with my reading of their homologies.

I have mentioned in the Palæontology of Ohio that *Macropetalichthys* occurs in the Devonian limestone of Germany, and have referred to the fact that the cranium of a species of this genus was described by von Meyer[1] with the name of *Placothorax Agassizi*, as he supposed his fossil to be generically identical with *Placothorax* of Agassiz; but these fossils have really no relationship with each other. *Placothorax* is nothing but the pectoral organ of a large species of *Pterichthys*. Von Meyer's specimen is also reversed, the occipital bone being taken for the nasal, etc. By reference to his figure[2] this will be seen at a glance. Unfortunately the tuberculated

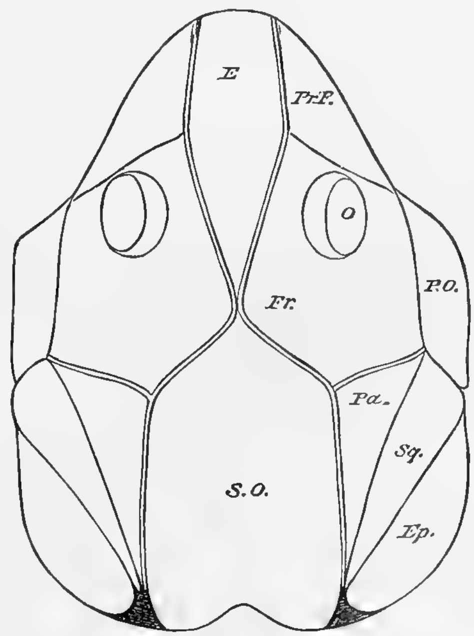

Fig. 2. Cranial plates of Macropetalichthys.

E. Ethmoid.	Fr. Frontal.	Pa. Parietal?
S. O. Supra-occipital.	O. Orbital.	Sq. Squamosal?
Pr. F. Pre-frontal.	P. O. Post-orbital.	Ep. Epiotic?

[1] Neues Jahrbuch für Mineral., 1846, p. 596.

[2] Palaeontographica, vol. 1, p. 102, Pl. XII.

enameled coating of the cranial plates is wanting, and we cannot make a detailed comparison with our species.

Recently I had an opportunity of seeing another specimen of *Macropetalichthys* in Berlin, where it was exhibited with other Devonian fishes found by Prof. A. von Koenen in Devonian strata near Göttingen. This is remarkably like our species *M. Sullivanti*, but is smaller and different in the ornamentation of the cranial plates. In our species they are closely set with stellate enameled tubercles, but in von Koenen's specimen the tubercles coalesce, running into convoluted parallel lines like the ornamentation of *Pterichthys* and *Acanthaspis*.

Genus ASTEROSTEUS, Newb.

Of this fish the cranium only is known, and of this all the specimens yet obtained are incomplete. The head was apparently long and narrow, the sides nearly straight, broadening suddenly in the occipital region. The posterior margin of the cranium shows two broad arches—one on either side of the main line—in which the cranial bones are deeply excavated, as though for muscular attachment. The skull is terminated behind by two conspicuous rounded projections, having the aspect of condyles, but which, so far as can be seen, show no articulating faces. The upper surface of the cranium is covered with relatively large, beautifully stellate tubercles, which vary considerably in size. Toward the nasal extremity are two linear furrows, which diverge from the middle line of the cranium and inclose two strongly marked elliptical pits that closely resemble the nostrils of some reptiles. In none of the specimens of this peculiar fish yet obtained have the outlines of the cranial plates been distinguishable, the surface being covered by a sheet of tuberculated enamel, by which the sutures are entirely concealed. On the sides the cranium is somewhat beveled off, as though for the attachment of some coriaceous or ligamentous appendage, or perhaps for co-adaptation to lateral head plates; none of which have, however, been found. The dentition of *Asterosteus* is quite unknown, as no jaws or teeth have been discovered with its remains.

Asterosteus stenocephalus, Newb.

Plate XXX, Fig 1.

Asterosteus stenocephalus, N.; Palæontology of Ohio, vol. 2, p. 35, pl. 54, fig. 1.

Head eight inches or more in length, by two and a half in width, except at the occiput, where it suddenly widens and becomes four or five inches broad. It terminates posteriorly in two excavated arches, of which the surface is roughened, apparently for muscular attachment. Projecting behind and below these arches are two bony condyloid prominences an inch or more in length. The upper surface of the cranium is somewhat irregularly covered with stellate tubercles, which vary in size from one-eighth to one-twentieth of an inch in diameter. The sides of the cranium are somewhat beveled and roughened, and are traversed by an irregular line of relatively large tubercles. Near the anterior end the head seems to be suddenly narrowed, and just at this point it bears two deeply impressed, elliptical nasal (?) orifices, placed side by side, somewhat divergent forward, and having a length of five lines and a breadth of two lines. The dentition is entirely unknown, as is also the covering of the body.

Formation and locality: Corniferous limestone; Sandusky and Delaware, Ohio.

Order HOLOCEPHALI.

Genus RHYNCHODUS, Newb.

In the Palæontology of Ohio (vol. 1, p. 307) I described a peculiar group of dental organs of Elasmobranch fishes, under the name of *Rhynchodus.* These occur not infrequently in the Corniferous and Hamilton limestones, but had not before attracted attention, simply because no one had interested himself in the vertebrate fossils of American Devonian rocks. The following is a brief generic description of these fossils:

Teeth somewhat crescent-shaped or semi-circular, much compressed; the exterior margins regularly curved, the interior nearly straight and more or less thickened; one of the cornua produced and somewhat acute, the other rounded and obtuse. The straight side formed a triturating or cutting edge. In some species it was sharp, and played upon the similar edge of

the opposite tooth; in others it was broader, and was fitted for crushing mollusks or other food. Internal structure of teeth cancellated; the triturating surface being roughened by the extremities of calcigerous tubes. The number of teeth and details of dentition are not yet known, but we may infer from their shape that they were placed at the anterior extremities of the head to form a kind of rostrum or beak, much as the dental plates of *Chimæra* are placed. As none of the margins show marks of contact with other teeth, we may conclude there were but four having this form.

The internal structure of these teeth varies somewhat in the different species, adapting each to its functions. In *R. secans* the central portion is cancellated by interwoven calcigerous tubes, while the surfaces are composed of tissue almost as dense as enamel, so that the cutting edges produced by the friction of opposing teeth on each other were kept constantly sharp and effective. In *R. frangens,* however, in which the upper edge is thick and presents a broad triturating surface to the opposite tooth, the dental tissue is cancellated throughout, affording by use that peculiar roughened surface seen on the teeth of Cestracionts (*Psammodus*, etc.).

Speaking of the zoological relations of *Rhynchodus* in the article referred to I used the following language:

> In regard to the affinities of *Rhynchodus*, it seems to me we have no good reason to doubt that they form the dentition of Chimæroid fishes, and that we have in them evidence of the existence on the globe of the *Holocephali* at a period long anterior to the date of the strata in which their oldest remains have hitherto been found. As has been stated in the general review of our fossil fishes, the Chimæroids of our present seas (*Chimæra* and *Callorhynchus*) are the remnants of an order of cartilaginous fishes which once held a much more important place than now in the fauna of the globe. In Europe the remains of the teeth of Chimæroids have been discovered in Tertiary, Cretaceous, and Jurassic strata, but none in older formations, if we except the somewhat anomalous *Ptyctodus* found by Pander in the Devonian of Russia.[1] * * * The affinities of *Ptyctodus* may be somewhat doubtful, although I have been inclined to consider the teeth described under this name as probably the dentition of some Chimæroid fishes.
>
> Whatever may be thought of the relations of *Ptyctodus*, those who are familiar with the fossil Chimæroids described by Sir Philip Egerton will probably not hesitate to group *Rhynchodus* with them.
>
> Although the *Holocephali* have heretofore been supposed to be limited in their downward range by the Jurassic formation, since we have evidence that our living

[1] Ueber die Ctenodipterinen des Devonischen Systems, p. 48, pl. 8.

Chimæroids are only the remnants of an expiring fauna, it was to be expected that the life of this fauna would be found to reach far back in time; and it was quite consistent with all the facts before known to find traces of Chimæroids in Palæozoic rocks.

The Rays, on the other hand, are apparently a comparatively modern off-shoot from the original Selachian stock. We have no evidence of their existence at a period anterior to the Jurassic age, and they are evidently now in their epoch of fullest development; while the Chimæroids, in their decadence, should naturally have had an earlier birth.

Since these notes were written Sir Philip Egerton has said in a letter to me that he had no doubt of the affinities of the fishes which bore the teeth of *Rhynchodus* with the Chimæroids of the present day, and as he has studied this family more carefully than any other naturalist, this conclusion will probably not be questioned.

Quite recently I have received from Mr. Thomas A. Greene, of Milwaukee, Wis., a number of fragments of the teeth of a large species of *Rhynchodus*, obtained by him from the hydraulic limestone quarries in the vicinity of that city. On another page I have described these remains and named the species after the discoverer. From Prof. T. C. Chamberlin, State geologist of Wisconsin, I have received a tooth of another and smaller species, found in the Hamilton rocks of Brown Deer, Wis. This species I have called *Rhynchodus excavatus*, and have briefly described and figured it in another part of this memoir.

RHYNCHODUS SECANS, Newb.

Plate XXVIII, Figs. 1–3.

Rhynchodus secans, Newb; Paleontology of Ohio, vol. 1, p. 310, pl. 28, fig. 1.

Teeth somewhat semi-circular in form, posterior angle rounded or obtuse, the anterior prolonged into a more or less acute point; posterior and inferior margins thin and sharp, anterior and superior margins thickened; lateral surfaces smooth, almost polished; interior face flattened, exterior sloping from the anterior and upper thickened edges to the thin margins behind and below; upper margin nearly straight; anterior half often worn to a sharp, knife-like edge by contact with the corresponding edge of the opposite and overlapping tooth.

Of these singular teeth I have quite a number from the upper portion of the Corniferous limestone at Sandusky and Delaware, Ohio. In outline

they form the segment—from one-third to one-half—of a circle, and are from three to four inches in length across the straight side. They were apparently four in number, so set as to form pairs of shears. All the specimens I have are considerably worn, the anterior half of the upper margin being beveled off to form a straight, acute, cutting edge.

In general form and structure these teeth correspond closely with those I have described under the name of *Rhynchodus frangens*, but are smaller, narrower, smoother, and much less thick and massive. They are also at once distinguishable by their cutting edges.

On Pl. XXVIII, Fig 1, is represented a tooth of *Rhynchodus secans*, showing a much-worn cutting edge. Fig. 1^a represents a section of the same. Figs. 2 and 3 are a pair of these teeth placed in their natural positions. All these figures are of natural size. Figs 2 and 3 are taken from a group of four found together, and forming apparently the dentition of a single fish.

Formation and locality: Corniferous limestone; Sandusky and Delaware, Ohio.

RHYNCHODUS FRANGENS, Newb.

Plate XXIX, Figs. 2, 2^a, 3.

Teeth semi-lunar in form, one side slightly concave, the opposite margin strongly convex and regularly rounded; type specimen four inches and eight lines in length, depth at the crown of the arch two inches and nine lines; sides flattened; greatest thickness, six lines; concave side showing a triturating surface on its anterior half and rising upward into a beak-like point; lateral surfaces smooth and polished; the lower and rounded portion of the tooth formed by thin walls of bone inclosing a deep cavity; crown portion thick and strong.

The above description is based upon a tooth that seems to exhibit an unusual perfection of preservation, as there are several in the collection before me which apparently represent the crown portion—the massive anterior angle with its beak-like point and triturating surface—while the broad and smooth expansion of the sides formed by the thin and shelly portion is altogether wanting. It is, however, possible that these are corresponding teeth from opposite jaws, of which one form exhibits a crown portion with

a broad expansion of marginal wall, inclosing, perhaps, a pulp cavity, while the other is simply concave below, for adaptation to the convex surface of a supporting jaw. Just such a difference, indeed, is seen in the teeth of the upper and lower jaws of *Callorhynchus.*

The microscopic structure of these teeth is similar to that of many of the teeth of extinct Selachians, such as *Cochliodus*, *Psammodus*, etc., viz, a cancellated or reticulated tissue formed by radiating and branching calcigerous tubes completely solidified near the exterior, but wearing in such a manner as to leave a peculiar roughened and punctate grinding surface. The general form of the most perfect of these teeth is very similar to that of those I have designated by the name of *Rhynchodus secans;* but in that species the lower margin is not so strongly arched, and the crown forms a cutting edge which played on that of the opposite tooth. If my view that these are the teeth of Chimæroid fishes is accepted, it will perhaps be thought that the differences between these two species have generic value, as they are quite as striking as those which separate the genera *Edaphodon*, *Ganodus*, *Ischyodus*, *Elasmodus*, etc. Yet, as it seems to me, with so little material before us and knowing so little of the complete dentition of either species, it would be somewhat premature to attempt now to define more than one genus.

The resemblance presented by these teeth to those described by Buckland[1] under the name of *Chimæra Townsendii* is so striking, that to any one who will make the comparison the question will seem to be not so much whether the teeth under consideration are those of a Chimæroid fish, as whether the present species and that of Buckland do not belong to the same genus.

Rhynchodus crassus, Newb.

Plate XXVIII, Fig. 4.

Rhynchodus crassus, Newb.; Palæontology of Ohio, vol. 1, p. 312, pl. 29, fig. 3.

Teeth large and strong, three to five inches in length, one and a half to two inches in breadth. Base expanded, with a somewhat semi-circular

[1] Proc. Geol. Soc. London, vol. 2, 1838, p. 206.

outline, from which the sides converge upward to an irregularly flattened and roughened crown, that rises at the anterior extremity into a pointed prominence; base excavated; crown thick and strong; upper surface showing attrition from use.

In the teeth described above we have a form of which a number of examples have been taken from the Corniferous limestone. None of these, however, are sufficiently complete to enable us to give all desirable details of their normal outlines and structure. So far as we can judge from this material, the original form of these teeth was not unlike that of the one I have described under the name of *Rhynchodus secans*, but they were evidently much thicker and stronger, and were fitted for crushing rather than for cutting. For the reasons already given I have been led to group these with the other teeth now described under the same generic title, and to regard them as the remains of fishes having more affinity with *Chimæra* and *Callorhynchus* than with any others now living.

Probably the accumulation of more material will enable future paleontologists to determine more accurately the relations of this group of fishes with each other and with our living fauna; and it is possible that their researches will modify in some degree the views now advanced. I have thought, however, that the publication of figures and descriptions of this singular group of fossils would at least serve a useful purpose in stimulating collections and researches by which their structure and relations would be more fully ascertained.

Formation and locality: Corniferous limestone; Sandusky, Delaware, and Kelley's Island, Ohio.

RHYNCHODUS EXCAVATUS, Newb.

Plate XXIX, Figs. 1, 1a.

R. excavatus, N.; Geol. Survey Wisconsin, vol. 2, 1877, p. 396.

Tooth small; size when entire perhaps two and a half inches long by one and a quarter deep; the crown alone preserved. Of this the external surface is marked vertically with vermicular furrows; superior margin sinuous, terminating anteriorly in a prominent point; the superior surface irregularly excavated and roughened, showing two elevations or tubercles,

one on the middle of the exterior margin and one near the anterior extremity. The inner surface of the tooth shows a prominent ridge running up to the anterior point.

This tooth is evidently fitted for triturating rather than cutting, and resembles in its general form *R. frangens*, of the Corniferous limestone. It is, however, much smaller and thinner; and the tubercles of the upper surface are situated differently from those in that species.

Formation and locality: Hamilton group: Brown Deer, Milwaukee County, Wis. Collected by Prof. T. C. Chamberlin.

Rhynchodus Greenei, n. sp.

Teeth large and massive, six inches in length, one inch in thickness at the anterior border; elliptical or semi-circular in outline, the anterior angle produced into a strong triangular point; posterior to this a triturating flattened surface extends to or beyond the middle of the superior margin. This surface is broadest anteriorly, where it is three-quarters of an inch in width, and bears two obtuse rounded tubercles. The sides are smooth and polished, terminating below in sharp, somewhat waved, edges.

The teeth of this species resemble those of *Rhynchodus frangens*, from the Devonian rocks of Ohio, but are narrower vertically, and are longer and much thicker at the anterior border.

Formation and locality: Hydraulic limestone of Hamilton age; Milwaukee, Wis. Collected by Mr. Thomas A. Greene.

Order PLACODERMI.

Dinichthys precursor, n. sp.

Plate XLI.

In the Corniferous limestone at Sylvania, Ohio, Mr. G. K. Gilbert, when connected with the Ohio Geological Survey, obtained a dorsomedian plate of what seems to have been a species of *Dinichthys*. It is about eight inches long by five inches broad; the sides nearly straight, the anterior border emarginate. The plate was transversely arched, nearly straight along its central line; the external surface in parts smooth or finely pitted,

in other portions set with scattered, somewhat remote, tubercles. The keel of the under side is buried in the rock, and its form cannot be made out; but one character is noticeable in which this differs from the dorsal shields of other species of *Dinichthys;* that is, the keel did not extend to the posterior border, and that border projected from its base in a flange five-eighths of an inch in width.

Unfortunately the specimen obtained by Mr. Gilbert remains unique, and little can therefore be said of the structure of the fish which it represents. It is, however, certain that this was the dorsal shield of a Placoderm belonging to the Dinichthidæ and probably to the genus *Dinichthys*, as no other is known to have had a dorsal shield of similar character. If so, it is interesting as being the oldest member of the genus of which we have any record.

COCCOSTEUS OCCIDENTALIS, Newb.

Plate XXV, Figs. 2, 2ª.

In volume 2, Palæontology of Ohio, page 32, pl. 53, figs. 2, 2ª, I have described and represented the dorsomedian and ventromedian plates of a small Placoderm which I have suspected to be a species of *Coccosteus.* A comparison of these specimens with the corresponding parts of the dermal defenses of *Coccosteus decipiens* Ag. and *C. cuspidatus* Ag. shows so strong a resemblance that the conclusion that they are generically identical seems fully warranted. As I have elsewhere stated, it also seems highly probable that the little mandible which I described[1] with the name *Liognathus spatulatus* was a jaw of the same fish. To this conclusion I have been led by an examination of the jaws of *Coccosteus* in the British Museum, some of which have been recently found, and are much more complete than those figured by Pander and Agassiz.

As the specimens referred to above remain up to the present time the only traces yet discovered of the existence of *Coccosteus* in America, more than usual interest attaches to them, and I have thought best to reproduce in this memoir the figures before published.

The Corniferous limestone has proved to be a great treasury of ichthyic remains, and there is little doubt that future collectors will find in it not

[1] Palæontology of Ohio, vol. 1, p. 306.

only many new things, but what will perhaps be more instructive, the missing parts of organisms but imperfectly represented in the collections hitherto made. Among these, portions of the structure of *Acanthaspis*, *Acantholepis*, and *Coccosteus* may be mentioned as special desiderata.

Order CROSSOPTERYGIDÆ.

Genus ONYCHODUS, Newb.

Ganoid fishes of large size; cranium composed of a large number of bony plates covered with enamel and tuberculated; tuberculation relatively fine, and formed by what may be compared to small grooved cones, pressed down and adherent; jaws set with numerous conical, acute, more or less recurved teeth of nearly uniform size; maxillary forming a low triangle, with much produced acute lateral angles; dentary bones posteriorly acute, where they are overlapped by the articular portions of the mandibles, long and narrow, curving upward to the symphysis, where they support an intermandibular arch of bone, to which was attached a single series of large, curved, conical teeth; teeth all smooth, covered with enamel, without basal plications; those of the maxillaries and mandibles implanted in sockets or anchylosed. The teeth of the median crest are seven or eight in number, attached (by ligaments?) to an arched base, from which they radiate. They are much curved, often sigmoidally, have a circular section near the summit, are somewhat compressed below, and expand at base into several prominent roots or tuberosities. They have a central cavity extending nearly to the point, surrounded by dentine simple in structure; the external surface is formed by a layer of smooth and polished enamel.

The body of *Onychodus* was covered with imbricated scales, nearly circular in outline, and about an inch in diameter. The under surface of the scale is marked by fine concentric lines, as in *Holoptychius*. The exposed portion of the outer surface is ornamented with a tuberculation not unlike that of the plates, consisting of radiating but broken lines, and confused groups of minute, furrowed, appressed cones.

This genus was established by the writer many years ago to receive certain conical, curved teeth found in considerable numbers in the Cornif-

erous limestone. Figures and descriptions of these teeth are given in an article on the fossil fishes of North America.[1] As they are generally found detached, nothing was known until recently of their relation to any other fish remains found in the Corniferous limestone, and as the most abundant cranium in this rock is that of *Macropetalichthys*, it was suggested that they formed part of the dentition of that fish After a time, however, some of these teeth were found associated together in rows of seven; an arrangement most like that of the teeth of Sharks. And as they seem to have been connected with their basal support by only ligamentous attachment, as the teeth of Sharks are attached to their jaws, this circumstance was regarded as confirmatory evidence of their Selachian character. It happened, however, in several instances that plates of various forms, maxillaries and mandibles set with teeth and numerous scales—each group evidently the fragments of a single individual—were found on slabs taken out of the quarries at Sandusky and Delaware. Among these fragments there was almost invariably a single series of the teeth of *Onychodus*. How to establish a relationship between these teeth and the associated remains, which were those of a well-marked Ganoid fish, was for a long time a puzzle; but by a fortunate discovery of Mr. Hertzer the problem was at last solved. He found at Delaware a large dentary bone of *Onychodus*, to which the peculiar series of large teeth are attached in their normal position; that is, between the extremities of the mandibles, where they hold the position of the median row in the dentition of a Shark. They are attached to a bony arch, from which they radiate. This is inserted in the symphysis of the jaw, supported by a shoulder on the internal face of the extremity of each mandible.

So far as we yet know, there are no corresponding or interlocking teeth in the upper jaw; and hence it would seem that they armed the projecting extremity of the under jaw, just as the steel point arms the prow of a steam ram. We shall probably find more perfectly preserved specimens, which will fully explain this apparently anomalous structure, and perhaps correct in some degree our conclusions in respect to it; but the specimens

[1] Notes on American Fossil Fishes; Am. Jour. Sci., 2d series, vol. 34, 1862, p. 73; also described in Bull. National Inst., Jan., 1857.

before me seem to establish beyond question the position of these teeth in the symphysis of the jaw.

The pattern formed by the numerous plates that compose the cranium of *Onychodus* is very complicated, and presents a puzzle not yet solved, for the cranium has never been found entire; and indeed it has rarely happened that any two plates have been seen in connection. In this we have evidence of a want of solidity in the structure of the cranium, such as has not been noticed among any of the congeners of this fish. A number of the plates which compose the bony structure of the head can, however, be easily identified, such as the opercula, parietals, frontals, etc, and all the plates which belong to *Onychodus* are easily recognized by their peculiar tuberculation. This is relatively fine, and may be compared to a series of small, striated, appressed cones. In some instances these cones show but a single furrow by which they are notched at the summit; their height is two or three times the diameter, but each is laid over and adherent to the plate by its entire side. A similar tuberculation, though finer, covers the exposed portions of the mandibles and maxillaries.

In regard to the affinities of *Onychodus*, it is impossible now to speak with absolute certainty, as all the specimens yet found have been in such a dismembered condition as to leave some important points of structure undetermined. There is little doubt in my mind that it belonged to the Crossopterygidæ. The features which lead to this conclusion are the cycloidal, imbricated scales, having the exposed portion strongly, the covered portion more delicately, yet elegantly, ornamented, much as in *Glyptolepis;* the spatulate or sandal-form jugular plates, and the large rounded opercula. Both these latter plates, as well as the supra-temporals, resemble in form those of *Polypterus.* Hence we may infer that when the structure of *Onychodus* is more fully made out, we shall find that the paired fins were more or less lobate, the body fusiform, and the general appearance not unlike that of *Holoptychius* and *Glyptolepis.*

The peculiar dentition I have described is a point in the structure of *Onychodus* where it differs widely from the fishes with which I have associated it; but I have elsewhere shown how much the dentition varies among both recent and fossil fishes, which by other characters are somewhat

closely approximated. It may also be said that while on some large slabs of limestone we have found apparently most of the bony portions of *Onychodus*, among these were no plates such as belong to the carapaces of the Placoderms; and we have, therefore, no evidence that it has any affinity with *Asterolepis*, *Coccosteus*, etc. The scales of *Onychodus* are not unlike those which were attributed by Hugh Miller to *Asterolepis;* but we now know that these scales really belong to *Glyptolepis*, and that, so far as known, the body of *Asterolepis* was without scales.

Since the above notes[1] on *Onychodus* were written, in 1873, two other species of the genus have been discovered, viz: *O. Hopkinsi*, N., and *O. Ortoni*, N., both of which are noticed on the following pages. But of the first only the intermandibular teeth have been found, and of the second a single intermandibular arch carrying teeth; so that they add little to what was learned from the abundant remains of *O. sigmoides* in the Corniferous limestone.

The descriptions and plates are here republished for the purpose of bringing together all the material yet known which can serve to illustrate the remarkable dentition of *Onychodus* and to enable the reader better to appreciate the comparisons which have been made between that and *Edestus*.

Onychodus sigmoides, Newb.

Plate XXXVI, Figs. 1–4[a]; Plate XXXVII, Figs. 1–10.

Onychodus sigmoides, N.; Palæontology of Ohio, vol. 1, p. 299.

Fishes of large size; head at least eighteen inches long, composed of numerous angular and rounded plates, supported on a cartilaginous brain-box, and so imperfectly united that in the fossil state they are usually disconnected and scattered. Of the head plates, the opercula are from three to five inches in diameter, nearly circular, but with a produced anterior angle. The maxillaries are triangular in outline, the anterior and posterior angles much produced, the lower margin nearly straight, and set with a large number of conical, pointed teeth. The dentary bone of the mandibles is often more than a foot in length, curved gently upward at its anterior extremity, which is rounded. Its posterior extremity is thin and flattened

[1] Palæontology of Ohio, vol. 1, pp. 296–299.

running off to a pointed edge, where it was overlain by the articular portion of the mandible.

The upper margin of the dentary bone is thickly set with conical, pointed teeth. Embraced within the anterior extremities of the mandibles is an arch of bone, which supports a series of large, conical, sigmoidally curved teeth, seven or eight in number, set vertically, and projecting downward, forward, and upward. These teeth show several prominent roots, which partially embrace the bases of the adjacent teeth. The exterior surfaces of the cephalic plates and the exposed portions of the maxillaries and mandibles are thickly set with small enameled tubercles, which have the form of appressed, striated, or sulcated cones. The body was covered with relatively thin, highly ornamented scales. These have a circular or elliptical outline; the under surface is smooth, or faintly marked with concentric lines, and often bears a central elevated tubercle or ridge. The exterior surface shows an anterior semi-lunar space, occupying about half its area, where adjacent scales were superimposed This space is comparatively smooth, but is delicately ornamented with radiating lines of pits. The posterior and exposed portion of each scale is roughened with appressed, striated tubercles, similar to those on the cephalic plates, and with branching, somewhat foliated ridges of enamel.

Formation and locality: Corniferous limestone; Columbus, Delaware, and Sandusky, Ohio.

Section B.—Fishes of the Hamilton Group.

In the State of New York the Hamilton group consists mainly of shales—argillaceous and bituminous—with only two thin bands of limestone, never over three feet in thickness in a thousand feet of strata. As we go westward and recede from the old shore the sheet of land-wash becomes thinner, the sandstones and clay shales of New York disappear, while the bituminous shales are more constant, running together and forming a mass, which in Ohio and further south is a very striking feature in the geology. I have called this in Ohio the Huron shale, because it forms for a long distance the banks of the Huron River, and as it represents several distinct strata in New York and Pennsylvania, it could not with propriety

take the name of either of them. By other geologists it has received various names, and has been regarded as the equivalent of each of several strata, distinct and somewhat widely separated in the east. The first geological corps of Ohio called it simply the black shale; Prof. E. B. Andrews, the Ohio black shale; Prof. Edward Orton, the Ohio shale; Prof. E. T. Cox, State geologist of Indiana, the New Albany black shale, etc., and it has been regarded as the equivalent of the Marcellus, and sometimes of the Genesee of New York. In fact it is neither, but rather both, and it also includes the western extension of the Portage and Hamilton shales. This is shown by the fact that in different localities it has yielded fossils of all these horizons, viz: *Clymenia complanata, Rhynchonella limitaris, Styliola fissurella, Discina lodensis, Lingula spatulata,* etc.

In Ohio the Huron shale is from three hundred to four hundred feet in thickness, contains from ten to fifteen per cent. of carbonaceous matter, and it is the principal source of petroleum and gas in New York, Pennsylvania, Ohio, and West Virginia. In most localities the formation is very barren of fossils; often in good exposures nothing being discoverable but obscure impressions of sea-weeds, which are thickly spread over the surface of the layers, and doubtless furnished the greater part of the carbonaceous matter.

In 1866 Rev. H. Hertzer, of Delaware, Ohio, found in calcareous septaria that abound near the base of the Huron shale some large bones which formed the nuclei of such concretions. These were submitted to me by him at the meeting of the American Association at Buffalo in 1866, and I recognized them as the plates and bones of large Placoderm fishes, up to that time undescribed. During the succeeding year Mr. Hertzer pursued his search for these fossils with great enthusiasm and success, obtaining nearly the entire bony structure of the great armor-clad fish which I described in the first volume of the Palæontology of Ohio under the name of *Dinichthys Hertzeri.* In this fish, while the general structure is similar to that of the other species of *Dinichthys* since described, the characteristic and distinguishing feature is the denticulation of the borders of the maxillary and mandible; in the others these borders are sharp edges, that play on each other like the blades of shears.

Mr. Hertzer also found in these concretions the bones of smaller individuals of *Dinichthys*, probably a distinct species, inasmuch as the form of the dorsal shield is different and the neck is relatively much longer than in *D. Hertzeri.*

In the shale outside the concretions Mr. Hertzer discovered the greater part of a dorsomedian plate which apparently belonged to a Pterichthoid fish. This was about eighteen inches long by thirteen inches wide, somewhat six-sided and short coffin-shaped; the exterior surface is set with large, smooth tubercles which may be compared to split peas. I have named this fish *Aspidichthys*, and have supposed that this was the central plate of a dorsal carapace, as it corresponds in form to that plate in *Pterichthys*, but is a hundred times larger in area. A few fragments of plates bearing this peculiar tuberculation have been found in the Huron shale at the Falls of the Ohio, but this seems to be the rarest of all the great Placoderms of which the remains are found in our Devonian and Lower Carboniferous rocks.[1]

No one has thoroughly explored the exposures of the Huron shale in Ohio and Kentucky, and yet fragments of the plates of fishes have been obtained from so many localities, that we may be sure a rich harvest will some time be gathered there. In the valley of Paint Creek, near Chillicothe, and in the cliffs bordering the Scioto and the Ohio near Portsmouth, splendid exposures of this shale may be seen, and there is little doubt that fishes may be found at all these localities.

In central Kentucky Mr. William Linney has found in the Huron shale, which forms a kind of border to the blue-grass region, many fragments of large fishes; among other things two dorsomedian plates much like those of *Dinichthys*, and quite as large. Outline sketches of some of these have been kindly sent to me by Mr. Moritz Fisher, of the Kentucky Geological Survey, but I have been unable to identify them with any of the fish

[1] Prof. A. von Koenen, of Göttingen, has obtained from the Devonian rocks of Germany what seems to be the central dorsal plate of another species of *Aspidichthys*, which he has called *A. ingens*, and described in vol. 30, Abhandl. der Königl. Gesell. der Wissen. zu Göttingen, p. 34, pl. 3, fig. 1. I have had an opportunity of examining this specimen, and confirm fully von Koenen's view of it. It scarcely differs from the plate discovered by Mr. Hertzer, except that the tubercles are much less uniform in size and the anterior margin is produced in a kind of point at the center. This plate is very strongly arched, while that obtained at Delaware is nearly flat; but this is doubtless in a large degree due to vertical pressure.

remains found in Ohio, and I suspect they represent a gigantic Placoderm as yet undescribed.

At Delaware, Ohio, Mr. Hertzer found in a bed of calcareous clay, lying immediately below the Huron shale, a number of small concretions, each of which has the jaw, plate, or tooth of a fish as its nucleus. The most complete of these I have described under the name of *Callognathus regularis.* In the black shale above he obtained a half dozen small crushing teeth of an otherwise unknown fish, which I have called *Goniodus Hertzeri.*

In the Portage, Genesee, and Marcellus bituminous shales of western Pennsylvania and New York a number of fish remains have been found at different times, but no one has systematically worked this field, although much new material is sure to be some time obtained from it.

In 1884 Mr. E. N. S. Ringueberg described[1] a dorsomedian plate of a fish to which he gave the name of *Dinichthys minor;* this name, as I have remarked elsewhere, was preoccupied, and I have renamed it *D. Ringuebergi.* This was obtained from the black shale of the Portage group, at Sturgeon Point, on the lake shore, twenty miles west of Buffalo.

Prof. J. M. Clarke, in 1885, described[2] the mandible of a species of *Dinichthys* to which he has given the name of *D. Newberryi;* this was from the Genesee shale and from the Naples beds. From the same formation Professor Clarke also describes (1) under the name of *Palæoniscus Devonicus* the scales and cranial plates of a Paleoniscoid fish; (2) a mass of minute quadrangular scales or dermal tubercles which he calls *Acanthodes pristis;* and (3) a portion of a dorsal spine with a single row of large denticles, named by him *Pristacanthus vetustus.* More material will be required to verify Professor Clarke's conclusion in regard to the generic relations of the last-mentioned fishes. No Acanthodians have been found elsewhere in a true marine sediment; those of England, Scotland, and Canada having all been obtained from what are apparently fresh-water deposits, and the shagreen of sharks, undistinguishable from the scales of Acanthodians, occurs in irregular masses in many formations.

In the bone beds of the Corniferous limestone at Columbus, Ohio, and North Vernon, Indiana, detached rhomboidal, plain, or ornamented tuber-

[1] Am. Jour. Sci., 3d series, vol. 27, 1884, p. 476. [2] U. S. Geol. Survey, Bull. No. 16.

cles are very common, and Mr. Hertzer has obtained from the top of the Corniferous at Delaware, Ohio, what seems to be the decomposed and shapeless body of a small Elasmobranch, covered with dermal tubercles, which when detached seemed simply enameled granules, but where in contact are arranged in rows and appear rhomboidal. In the Marcellus shale of New York Mr. C. E. Beecher has also found masses of similar tubercles associated with small furrowed spines which may have been borne by an Acanthodian, but perhaps by a Selachian.[1]

The fragment of a spine called by Professor Clarke *Pristacanthus vetustus* is certainly very unlike anything we have elsewhere found in our Paleozoic strata, and resembles the spines obtained by Agassiz from the Jurassic rocks, and called by him *Pristacanthus securis;* but I would call attention to the spine described by Giebel, figured by Kayser[2] and named *Ctenacanthus abnormis.* This spine has the shaft longitudinally striated, and on the posterior margin bears a flange set with a single row of large denticles. Hence it does not belong to the genus *Ctenacanthus*, in which the longitudinal ridges are always pectinated or tubercled and the posterior margin is flattened or furrowed and is set with two rows of denticles. Giebel's specimen is also certainly distinct from Agassiz's *Pristacanthus*, but if the flange were broken off and alone preserved it might be readily mistaken for it. Only a fragment of the posterior portion of the spine is shown in Professor Clarke's specimen, and it is possible that this was attached to a shaft somewhat like that of the spine obtained by Giebel from the Devonian rocks of Germany. In any case the spine described by Professor Clarke would seem to require a new generic name.

The late Prof. F. H. Bradley collected from the Marcellus shale of New York a large number of the remains of fishes, principally detached teeth, which represent several new species, but they are impregnated with pyrites, are unsatisfactory subjects for study, and have not yet been described. They are in the cabinet of Yale College.

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[1] From the Berea shale at Vanceburgh, Ky., I have patches of similar shagreen associated with the teeth of *Orodus* and *Cladodus*, and with the spines of *Ctenacanthus* (Palæontology of Ohio, vol. 2, pl. 59, fig. 4); also from the Berea grit, at Berea, Ohio, patches of rhomboidal dermal tubercles found in proximity with the spines of several species of *Ctenacanthus*.

[2] Die Fauna der ältesten Devon-Ablagerungen des Harzes, Abhandl. geol. Specialkarte preuss., etc., Atlas, pl. 1, fig. 19.

Prof. O. C. Marsh has a number of large fragments of Placoderm fishes obtained from the Huron shale at the Falls of the Ohio; they apparently represent one or more new species, but are too imperfect for satisfactory description.

From the Moscow shale, Kashong Creek, Yates County, N. Y., Mr. Berlin H. Wright has obtained a large and fine spine of *Ctenacanthus*, which is distinguished from all other described species of the genus by its perfectly straight form, as well as by minor details. It is figured and described[1] with the name of *Ct. Wrighti*, and is noticed on another page of this memoir.

In the Hamilton rocks of Iowa, which are chiefly limestone, a considerable number of fish remains have been found, a few of which have come under my observation. Of these the most important are two species of *Rhynchodus*[2] apparently distinct from those found in Ohio, viz, *R. occidentalis* N. and *R. Greenei*, n. sp., which will be found characterized in the present monograph; the latter obtained through Mr. Thomas A. Greene, of Milwaukee. From Mr. Greene I also have a fish spine of a peculiar and interesting structure, which I have made the type of a new genus, *Heteracanthus*, of which a description will be found on another page. These specimens were found in the quarries of hydraulic limestone near Milwaukee, and with them were fragments which indicate the presence of a varied fish fauna in that formation.

From Mr. A. F. Tiffany, of Davenport, Iowa, I have received a fine specimen of *Ptyctodus calceolus*,[3] N. & W. The specimen from which the species was originally described was from the Hamilton beds of Calhoun County, Ill. From the same horizon in Rock Island County, Ill., I have a large number of what seem to be the teeth of a distinct species of *Ptyctodus*, but they may be only a dwarf form of the same. These latter teeth are small—an inch in length by a quarter of an inch broad—and show all the variation of form represented by Pander's figures.[4]

The zoological relations of *Ptyctodus* still remain uncertain, but there is little doubt that it was an Elasmobranch, and probably a Chimæroid. The

[1] Thirty-fifth Annual Report New York State Museum Nat. Hist., 1884, p. 206, pl. 16, figs. 12–14.

[2] Described in the Annals of the New York Academy of Sciences, vol. 1, p. 192.

[3] First described in Geol. Survey of Illinois, vol. 2, 1866, p. 106, pl. 10, fig. 10, as *Rinodus calceolus;* and later in the Palæontology of Ohio, vol. 2, p. 59, pl. 59, figs. 13, 13a, 13b.

[4] Die *Ctenodipterinen* der Devonischen System, pl. 8.

teeth are excavated below and were apparently set upon a cartilaginous jaw, as in *Rhynchodus* and *Chimæra;* they are usually of the shape of a shoe, from one to five inches long, the place of the opening in a shoe filled with an enameled, transversely ridged, triturating surface. In some teeth this enamel portion is raised, in others depressed, as though one fitted into the other. The motion of the jaws must have been forward and back, and the grinding apparatus is as complete as that possessed by the elephant. None of the teeth of *Ptyctodus* seem to have been found in Germany, England, or the eastern United States; but in the Devonian rocks of Russia, Iowa, and Illinois they are quite numerous.

The Devonian fishes of Canada have been already alluded to. Many years ago spines of *Machæracanthus sulcatus* were sent to me for examination by Sir William Dawson, and I have since received them from several localities.

From the Devonian rocks of Gaspé a species of *Cephalaspis* was obtained some years since by Sir William Dawson, and was named by Mr. Ray Lankester *C. Dawsoni.*

In 1880 Mr. A. H. Foord, of the Geological Survey of Canada, collected from the Devonian rocks on the shore of Scaumenac Bay, Province of Quebec, a large number of very interesting fossil fishes, which were subsequently described by Mr. J. F. Whiteaves.[1] These include *Pterichthys, Diplacanthus, Phaneropleuron, Glyptolepis* (two species), *Cheirolepis*, and a new genus described by Mr. Whiteaves under the name of *Eusthenopteron*, so named from its strong fin rays.

Previous to this discovery no species of *Pterichthys, Cheirolepis, Phaneropleuron* or *Glyptolepis* had been found in North America, and in an earlier review[2] of the fossil fishes of this country I noted "the absence from all our collections of many of the most abundant and best-known genera of the Scotch and English Old Red Sandstone fishes." On the other hand, I called attention to the fact that up to that time (1873) all the most important ichthyolites of our American Devonian were unknown in Europe; accounting for the difference between the Devonian fishes on opposite sides of the Atlantic by saying that our fishes were mostly obtained from the Cor-

[1] Canadian Naturalist, vol. 10, p. 93. [2] Palæontology of Ohio, vol. 1, p. 273.

niferous limestone, plainly a marine and relatively deep-water sediment, while the Old Red Sandstone, which had furnished most of the fossils found abroad, was probably a lake deposit. The fifteen years which have elapsed since the publication of my former review have confirmed the conclusion then reached, but have compelled me to modify some of my statements of act; for not only has a fresh-water fish fauna been discovered in Canada which closely resembles that of the foreign Old Red Sandstone, but in the marine limestone of Germany *Dinichthys, Aspidichthys, Macropetalichthys* and *Machæracanthus* have now been obtained, so that the discrepancy between the European and American Devonian fish faunas has ceased to exist by the discovery in each country of similar fossils in similar deposits.

DINICHTHYS HERTZERI, Newb.

Plate XXXII, Fig. 2.

Dinichthys Hertzeri, Newb., Palæontology of Ohio, vol. 1, p. 316, pls. 30–37.

In the first and second volumes of the Palæontology of Ohio the two largest and first-found species of *Dinichthys* are so fully illustrated, that they require no detailed description here. Of *Dinichthys Hertzeri*, from the Huron shale, we have no more new material. The Rev. H. Hertzer, who first discovered the species at Delaware, Ohio, and who cultivated that field with so much enthusiasm and success, changed his residence, and the exposures of the Huron shale in central Ohio have been of late neglected. On the Huron River, in Erie County, and in the valleys of the Scioto and many of its tributaries in southern Ohio, the formation is very extensively opened, and we have proof that it everywhere contains calcareous concretions within which are bones, but no one has been favorably located for collecting in these districts.

There are some important points in the anatomy of this species of *Dinichthys* of which we are still ignorant. The head, with its complete dentition and the dorsomedian plate, we have, but the defenses of the under side of the body have never been clearly made out. I have seen in some of the concretions broken open by Mr. Hertzer at Delaware traces of a plate nearly two feet in diameter, which does not correspond to anything known

in the defensive armor of *D. Terrelli*, and I have suspected that, like *Titanichthys*, the body was perhaps protected below by a single great shield. I have also a plate of *D. Hertzeri*, which, though incomplete, is triangular in outline, nearly three feet long and a foot wide at the broader end. This probably constituted the protection of the side of the body, but nothing just like it has been found in connection with the species of *Dinichthys* from the Cleveland shale. These suggested rather than demonstrated differences of anatomical structure have led me to think that, when all the plates and bones of *D. Hertzeri* shall have been found, they will show divergencies from *D. Terrelli* which will perhaps be thought to have generic value. This question, however, cannot be decided at present, and will perhaps remain for the consideration and decision of palæontologists of another generation. I have elsewhere referred to the discovery of the dorsomedian plates of a large Placoderm in the Huron shale of Kentucky, and also to the discovery in the same formation at Louisville of large fragments of bone which have not yet been classified It is evident, therefore, that the southern extension of the Huron shale offers a field for future exploration from which much is to be hoped, particularly for the complete elucidation of the structure of *Dinichthys* and *Aspidichthys*.

HETERACANTHUS, nov. gen.

Pectoral (?) spines eight inches or more in length, robust, with a posterior opening reaching to or near the summit; base compressed, one and a half inches wide, obliquely rounded below, shaft curved forward, regularly arched transversely, covered with highly polished enamel, and marked by fine denticulate longitudinal sutures, which divide the surface into broad nearly equal bands or flattened ridges. The sutures are most numerous below, but terminate in succession above, so that few reach the conical pointed summit.

These spines are quite unlike any heretofore found in our Paleozoic rocks. They will be recognized at once by their want of symmetry, reversed curve, smooth and polished surface, and sinuous or denticulate longitudinal sutures.

Up to the present time no teeth have been found associated with these spines, except those of *Rhynchodus*, and we may suspect that they belong together. If this were true, it would be strange that no similar spines have been found with the very numerous teeth of *Rhynchodus* in the Corniferous limestone of Ohio.

Heteracanthus politus, n. sp.

Plate XXI, Figs. 4, 5.

Spine eight to ten inches long, compressed laterally at base, which is obliquely rounded below; summit curved forward, conical, with a subtriangular section. Anterior margin uniformly arched, sides flattened toward the base, lower two-thirds of posterior face open; upper third flattened; sides of unequal breadth, making the spine unsymmetrical.

The want of symmetry of these spines as well as their reversed curve renders it almost certain that they are the defenses of the pectoral fins They resemble in these characters *Physonemus*, but are without tubercles of any kind, and have in the minutely sinuous sutures a character so peculiar, that I have given it generic value.

Formation and locality: Cement beds of Hamilton age, Milwaukee, Wis. Collected by Thomas A. Greene.

Ctenacanthus Wrighti, Newb.

Plate XXVI, Figs. 4–4a.

Ctenacanthus Wrighti, Newb., Thirty-fifth Rept. N. Y. State Museum, 1884, p. 206, pl. 16, fig. 12–14.

Spine of large size, long-triangular in outline; anterior margin straight, laterally compressed; medullary cavity large, open posteriorly to the middle of the spine; posterior surface traversed above by a strong rounded ridge; denticles small; surface of exposed portion entirely covered with closely pectinated ridges of nearly uniform width on the front and sides, becoming narrower and less distinctly pectinated near the posterior margin.

The spines of this species are very striking in their characters as regards both form and markings. The anterior margin seems to have been absolutely straight from base to summit. Along the line of junction between

the enameled and buried portions the spine must have been two inches wide, but it tapered rapidly upward, terminating in a slender acute point. The exposed surface is more completely covered with ridges similar in character, and the pectination is more crowded than in any other species known to me. In its broad base and its general and uniform ornamentation this spine has some resemblance to *C. speciosus*, St. J. & W., specimens of which have been in my hands, but the line of demarkation between the ornamented and buried portions is less oblique, showing that the spine was more erect; the ridges are considerably coarser and the form is straighter. The pectination is also less oblique and closer, compared with the coarseness of the ridges.

Formation and locality: Hamilton group, near the middle of the Moscow shale; Kashong Creek, Yates County, N. Y., where it was obtained by Mr. Berlin H. Wright, for whom it is named.

GONIODUS, nov. gen.

Teeth numerous, composing a roughened pavement, small, variable in size and form; generally subtriangular in outline, depressed, with the central portion elevated into an obtuse angular ridge of denser tissue, and having a polished surface; other portions of the crown and the lateral margins roughened by a vermicular pitted or corrugated marking; the lower surface rough and bone-like.

We have in these teeth another of the many phases of the dentition of the fishes of which the food consisted of crustaceans or mollusks with more or less resistant shells. Undoubtedly a large number of ancient as well as modern fishes were vegetable feeders, and it is possible that some of what are called crushing teeth may have been employed for triturating vegetable tissues; but the sea-weeds, which must have composed the food of herbivorous fishes, were soft and succulent in character, and no more powerful organs were required for the management of this kind of material than such as would suffice to tear off fragments of the tender fronds, and these, like the other food of fishes, must have been swallowed without mastication. Nor are we to suppose that the powerful pavement teeth of the ancient carnivorous fishes were ever used to masticate food after the manner in

which it is done by the higher animal, but where that food consisted of mollusks or crustaceans inclosed in shells it was necessary that these shells should be crushed, and the fragments, perhaps in part rejected, in part reduced to such size that they could be conveniently and harmlessly swallowed. All the marine living fishes which have pavement teeth are supposed to be carnivorous, and in many of the fossil fish teeth we find evidences of much local wear, showing that mollusks with somewhat strong shells were brought to the point where they could be operated upon with the greatest mechanical advantage, and were there crushed, as nuts are cracked by pigs and other animals We find, too, many devices for holding in position the object to be crushed. Generally the individual teeth are blunt-pointed, projecting above the surface in such a way as to retain the food in place. In the dentition composed of flatter and smoother teeth, as in *Psammodus*, *Deltodus*, etc., the same object is less perfectly accomplished by a peculiar roughening of the surface by small pores; while in *Archæobatis*, as in the modern *Rhyncobatus*, the surface of the teeth is roughened by a beautiful transverse corrugation. From these essentially flat teeth the first departure is made in the teeth with arched or ridged surfaces of *Trigonodus*, *Deltodus*, *Sandalodus*, etc., with which those now described should probably be grouped as having similar forms and functions. Next come *Helodus*, *Chomatodus*, and *Orodus* with teeth which are still blunt, but have points or ridges projecting sufficiently from the general surface to afford a firm hold of softer and more slippery substances. From these blunt-pointed and ridged teeth the transition is easy to the sharp-pointed piercing teeth of *Cladodus*, *Hybodus*, and *Lamna*, admirably adapted to catching and holding the most slippery and evasive prey; or to *Chomatodus* and the blunt species of *Polyrhizodus*, of which the teeth in form and function resemble those of the Rays; thence on to the teeth of the *Petalodonts*, which, with the increasing sharpness and elevation of their cutting edges, lead to the terrible, serrated, lance-pointed blades of *Carcharodon*.

The affinities of *Goniodus* can at present hardly be conjectured. Some of the smaller teeth of *Ptyctodus*, so common in the Hamilton rocks of Iowa, exhibit considerable resemblance to these; but all the teeth of *Ptyctodus* show something of the peculiar transverse striation of the flattened crown

which constitutes the distinctive character of the genus, and which has so much resemblance—if we may compare small things with great—to the triturating surface of the crown of a molar of *Elephas.* The general form of the teeth of *Ptyctodus* makes it probable that this was a Chimæroid fish, but the teeth of *Goniodus* indicate no such relationship, and the larger ones, both by their form and the character of the lateral surface, rather suggest *Pœcilodus.* Probably *Goniodus* was an Elasmobranch and a Cestraciont, but of this we cannot be certain until more material shall have been gathered.

The type, up to the present time the only known species, is that described below.

Goniodus Hertzeri, n. sp.

Plate XXVII, Figs. 11–15.

Teeth small and varied in form, triangular or oblong in outline, depressed, with more or less of the central portion raised into a simple, smooth, obtuse-angled ridge; other portions of the surface punctate or vermicularly roughened; under surface flattened, somewhat rough and bony.

No full description of the dentition of *Goniodus* can yet be given, for only a small portion of the large number of pavement teeth, with which each jaw was furnished, have yet been obtained. These are, however, quite sufficient to show that they represent a new genus and species, interesting alike from its structure and from its geological position, which has hitherto furnished no other fish teeth at all like them.

Formation and locality: Huron shale; Delaware, Ohio. Collected by Rev. H. Hertzer, to whom it is dedicated.

CALLOGNATHUS, nov. gen.

Small fishes, of which only the mandibles are known. These are from one to three inches in length; the posterior end of the dentary bone flat, thin, spatulate, smooth; the anterior half narrower, thicker, and ornamented; the upper edge closely set with numerous subequal, conical, obtuse, blunt-pointed teeth.

But little can be said in regard to the affinities of these fishes until more of their structure shall be known. The form of the mandible is essentially

like that of *Dinichthys* and other members of the same family, viz, the posterior end is spatulate and smooth, and was once buried in cartilage; the anterior end, ornamented and bearing teeth, was evidently exposed.

CALLOGNATHUS REGULARIS, n. sp.

Plate XXVII, Fig. 18.

Dentary bones one to one and a half inches long, nearly straight, slightly curved upward at the anterior extremity, which is obliquely rounded; posterior end broader, thin, smooth, rounded, spatulate, as in all the Dinichthidæ; upper margin of dentary bone set with closely approximated, cylindrical, blunt-pointed teeth.

Only two of these little jaws and no other portion of the fishes which bore them have yet been found. These are, however, so clearly defined, and so distinct from any other fish jaws known, that it has seemed best to describe and name them. Their most obvious character consists in the very regular and uniform row of teeth with which the upper margin of the dentary bone is set. I know of no other fish jaws which have teeth so uniform in size and so closely set.

Formation and locality: Huron shale; Delaware, Ohio. Collected by Rev. H. Hertzer.

CALLOGNATHUS SERRATUS, n. sp.

Plate XXVII, Figs. 16, 17.

Dentary bone two inches in length, posterior half spatulate, anterior half long-triangular in outline; anterior end rounded, upper margin nearly straight, and bearing about twenty closely approximated, compressed, conical, lancet-shaped teeth, inclined backward, and increasing in size from front to rear; exposed surface of mandible ornamented with irregular longitudinal raised lines of enamel.

I have somewhat doubtfully associated the little jaw described above with those found by Mr. Hertzer in the Huron shale at Delaware, Ohio, and future discoveries may show that they should be referred to different genera. The dentary bones have approximately the same form and ornamentation, the upper margin of the anterior half in both is set with teeth, which are

remarkable for their close proximity and regularity, but the jaws from Delaware are much smaller and the teeth are apparently less acute. They are evidently closely allied, if not generically identical.

In both the Huron and the Cleveland shales we occasionally find, scattered or in coprolites, rhomboidal polished scales similar to those of some species of *Palæoniscus*, and I have supposed it probable that they belonged to precursors of the Paleoniscidæ so abundant in the overlying rocks.

These little jaws may naturally be supposed to have appertained to the same fishes with the scales, but it is evident that the fishes which carried the jaws could not have been Paleoniscids, since the form is that which prevails among all the larger fishes of the group of Dinichthidæ, namely, the posterior half spatulate, smooth, evidently once buried in integument and sheathed by cartilage; the exposed portion thicker, denser, ornamented, and carrying along the upper margin a single row of nearly equal teeth, developed from the condensed jaw-tissue.

In the Palæoniscidæ, on the contrary, the dentary bone is relatively much longer, is spliced on to the angular and articular portions of the mandible, and carries several rows of acute, conical teeth of unequal sizes. But more material will be required before anything positive can be said in reference to the fishes which bore the jaws I have called *Callognathus.*

Formation and locality: Cleveland shale; Lorain County, Ohio. Collected by Mr. J. Terrell.

ONYCHODUS ORTONI, n. sp.

Plate XIX, Fig. 1, 1ª.

Intermandibular bone one and a half inches long by one-half an inch in width and one-quarter of an inch in thickness; long-ovoid in section, broadest above, regularly arched in outline; its superior surface set with six equally spaced, recurved, acute, enameled teeth, *implanted in the bone* along the median line; these teeth are about equal in size, being one inch in length from point of insertion; the surface enameled and highly polished; section slightly compressed laterally; anterior margin rounded; sides flattened, and marked with three longitudinal planes, giving a somewhat angular section; the acute apex is turned forward.

Only the intermandibular bone of this fish has yet been found. In size and general aspect this arch with its row of teeth resembles the corresponding organ in *Onychodus Hopkinsi* of the Chemung, but may be dis tinguished from that at a glance by the very different manner in which the teeth are attached to the bony arch. In *O. sigmoides* and *O. Hopkinsi* the teeth of the intermandibular crest are expanded at the base with root-like projections on either side, which clasp the summit of the arched bone as a saddle the back of a horse. As their attachment was only ligamentous, they were deciduous, like the teeth of Sharks, and are very frequently met with detached from their bony support and scattered over the sea bottom. In the present species, however, the mode of attachment is very different, for they are implanted in the substance of the arch which sustains them as a post is planted in the ground. The mandibular and maxillary teeth of the other species of the genus are inserted in the substance of the jaw, and it has been a matter of surprise to find the much larger teeth of the intermandibular crest less firmly attached. From this circumstance I have suspected that the teeth of this median row might be erectile, like some of the teeth of *Lophius*. It is evident, however, that in the species now under consideration the teeth were much more firmly set, and must break rather than bend before a too-powerful opposing force. In the specimen before us this accident has happened, since one of the central teeth was broken off at about its middle before fossilization.

The specimen on which this description is based, and the only one known, was obtained by Prof. Edward Orton, from the Huron shale, Perry Township, Franklin County, Ohio. In age this deposit is intermediate between the Corniferous limestone below and the Chemung rocks above, in which *Onychodus sigmoides* and *O. Hopkinsi* respectively occur; and it is remarkable that the present species, intermediate in time between the others, should be so radically different in structure.

Genus ASPIDICHTHYS, Newb.

A Placoderm fish of large size, having a carapace composed of massive bony plates, of which the middle one of the back is similar in form to that of *Pterichthys*, but many times larger, and is covered with large, hemispherical, smooth, enameled tubercles.

Up to the present time one nearly entire dorsomedian plate and a few fragments of others are all that we have obtained of this fish. When other portions of the plate armor shall be found they will probably be seen to correspond most nearly with those of *Pterichthys*. The tuberculation of the surface is, however, very different, and as the dermal ornamentation is characteristic in these old fishes, it is here undoubtedly indicative of differences which have generic value.

ASPIDICHTHYS CLAVATUS, Newb.

Plate XXXVIII, Figs. 3, 4.

Aspidichthys clavatus, Newb.; Palæontology of Ohio, vol. 1, p. 323, pl. 35, figs. 1, 2.

Of this large and remarkable fish very little is known, as only some portions of the dorsal plates have yet been found. These are, however, so peculiar and so different from anything else known to paleontologists, that they will serve to identify unmistakably one of the largest and most singular of the great Placoderm fishes that inhabited the Devonian seas.

The most significant fragment of *Aspidichthys* yet discovered is a nearly entire median dorsal plate obtained by Mr. Hertzer from the Huron shale at Delaware, Ohio. This plate is an elongated hexagon, or is of short coffin-shape, having, indeed, almost exactly the form of the dorsomedian plate of *Pterichthys*, but being a hundred times as large; for, while the largest plate of *Pterichthys* is twelve to eighteen lines, the corresponding plate of *Aspidichthys* is as many inches in each diameter, or, more exactly, is thirteen by seventeen inches, and a portion of it is wanting. It is more than an inch in thickness in the central portion, and is keeled below, as is the same plate in *Dinichthys* and *Homosteus*. The most striking feature in this plate is, however, its external ornamentation. This consists of knobs or bosses of smooth, shining enamel, of the size and form of split peas.

In its general aspect this tuberculation resembles that of *Pterichthys* and *Coccosteus*, but differs strikingly in this, that the tubercles are perfectly smooth and polished, and show little of the stellate ornamentation which is to be seen on the plates of nearly all the great mailed fishes of the Old World. This character has doubtless generic value, but the form of the

dorsomedian plate is so nearly that of the same plate in *Pterichthys Milleri*, that if it were not for this peculiar tuberculation we might conclude that we had in this fish nothing more than a huge *Pterichthys.*

The margins of the plate under consideration are beveled off and straightened in such a way as to prove that it articulated with others, and there is no reason to doubt that it formed part of a carapace similar to that of *Pterichthys.*

Fig. 3 represents the dorsomedian plate of *Aspidichthys* very much reduced; Fig. 4 a portion of the same, natural size.

PART III.

FISHES OF THE CARBONIFEROUS SYSTEM.

FISHES OF THE CARBONIFEROUS SYSTEM.

The rocks which compose the Carboniferous system form three natural groups, as follows:

Upper Carboniferous ...	Permian. Coal Measures. Millstone grit.
Middle Carboniferous ..	Mountain limestone.
Lower Carboniferous...	Waverly. Catskill (local, fresh-water deposit). Chemung.

These strata, like those composing the other great circles of deposition, were formed by the advance, sojourn, and retreat of the sea, which left its record in a mechanical base, an organic center, and a mixed summit. The Carboniferous inundation was one of wide extent and long continuance, as we learn from the great thickness of the organic sediments which accumulated slowly over the bottom of those portions of the invading sea where the water was pure and deep enough to form limestone. This calcareous mass is in Kentucky 1,200 to 1,500 feet in thickness, thinning out toward the old shore line, where only the upper divisions of the limestone are present—showing a progressive subsidence—and are finally replaced near the permanent land area by a great thickness of land wash, conglomerate sandstone, and shales. In the geological history of the North American continent we find records of three of these *great* inundations, viz: The Lower Silurian, in which the marine sediments are widely spread and 1,000 feet thick; the Carboniferous, just described; and the Cretaceous, in which the limestones are of even greater extent and thickness.

Subsequent to the deposition of the Mountain limestone the eastern half of the continent was affected by great physical disturbances. These

were ushered in by a shallowing of the sea and a spreading of sheets of sandstone and conglomerate—the Millstone grit—over a large portion of the bottom of the interior basin. These fragmental strata were deposited by violent action of shore waves and strong currents, which in many places deeply eroded or tore up the old sea bottom, and left in its place thick beds of gravel and cross-stratified sand. In some localities, as in northern Ohio, the conglomerate contains great numbers of imperfectly rounded fragments of the cherty layers of the Mountain limestone; showing that this formation once existed there and that it has been extensively worn away.

During the deposition of the Coal Measures there were great changes of level; land, shore, and deep-water conditions alternating repeatedly in the same locality. Gradually a series of ridges and troughs were produced parallel with the old axis of the Blue Ridge, and in the irregularly subsiding troughs the coal strata—old peat beds—were formed at the water level, and successively buried by subsidence and the deposition over them of gravel, sand, clay, and marl; now conglomerate sandstone, shale, and limestone.

Naturally the life of the Carboniferous age was distributed according to these differences of physical conditions. On the land grew forests composed of the characteristic vegetation of the age; in the lakes and rivers were mollusks and fishes adapted to their places of residence; while in the sea different groups of marine animals inhabited the shallows and the deeper basins.

Owing to the long continuance of the Carboniferous age and the diversity of habitat offered them, the forms of invertebrate and vertebrate life buried in the strata are exceedingly diversified. Among the fishes—which are the objects of the present investigation—the number of genera and species already described is large, and yet we have evidence in the constant additions making to the list that our knowledge of the fish fauna is yet very imperfect. We have learned enough, however, to be warranted in saying, (1) that fishes were much more numerous and varied in this than in the preceding age, though that is called *the age of fishes;* (2) that the Elasmobranchs were far more numerous and powerful than in the Devonian sea; (3) that the Ganoids and Placoderms had been largely superseded by the

Sharks, and were, for the most part, driven to the shores and bodies of fresh water.

The influences which produced the great revolution in the fish fauna between the Devonian and Carboniferous ages are unknown to us, and will perhaps always remain so. If the interval was a long one, we can imagine that the changes took place in the sea basins, whose sediments are beyond our reach, and in the natural way of spontaneous variation, and the survival of the fittest; but here as elsewhere in geological history we must wonder at the absence of transitional forms. During the deposition of the great mass of the Mountain limestone, where it is at least 1,200 feet in thickness, there was a change of fauna that has led geologists to divide the mass into four groups: the Burlington, Keokuk, St. Louis, and Chester beds; which, with much in common, have each certain fossils peculiar to itself. But we do not find what we should naturally expect, that these differences are the results of gradual modifications of the earlier into the later species. Connecting links are wanting, and the changes of fauna seem to have been produced by importation rather than modification. Where, as in Kentucky, this great mass of organic débris has been produced by the growth, death, and disintegration of successive generations inhabiting the sea at the same place, it would seem inevitable that we should find abundant evidence of the transformation of the older species into the later. But little or nothing of this kind has been discovered. Certain species run through the entire mass with little perceptible change, while others are added as though by importation. This is a problem which will undoubtedly occupy paleontologists for ages to come, and with more abundant material its solution may be made clear to all. At present it is beyond our reach.

One striking peculiarity of the Elasmobranch fishes of the Carboniferous age is, that so many of them were provided with defensive spines. It it true that this feature was not confined to the Carboniferous Sharks, for the spines of *Machæracanthus* in the Devonian, and those of *Hybodus* in the Jurassic, are perhaps as formidable as any others; but the defensive spines found in the Carboniferous rocks outnumber ten to one those of all the other geological systems, and they surpass in very much greater proportion anything we find in the living fauna. Sharks are very numerous and formi-

dable in our present seas; and in the Tertiary the great *Carcharodon megalodon* was perhaps the most terrible of all the carnivorous inhabitants of the sea, yet it was apparently unarmed, except by the huge lancet-shaped teeth, as large as one's hand, with which its cavernous mouth was thickly set. Like nearly all Sharks of modern date, it was without defensive fin-spines, while in the Carboniferous seas hundreds of species bore these defenses, which show an almost infinite series of modifications for securing great effectiveness. Even in the Upper Silurian the first of the Sharks, *Onchus*, seems to have been provided with these organs, and in the Devonian and Carboniferous ages the fashion was adopted by many other fishes; the Acanthodians, for example, bristled with spines, and from this characteristic have taken their name. So the Placoderms sometimes added to the negative defenses of their plate armor pectoral and perhaps dorsal spines, which must have assisted in repelling their enemies.

It may be said that we have no information in regard to the number of defenseless Sharks in the Carboniferous sea, but if such Sharks could leave no spines as proof of their existence they must have been provided with the other bony organs of the Elasmobranchs—teeth and dermal tubercles. These we find abundantly in the ancient sediments, but when we group them in genera and species, we see that the variety of dermal tubercles is far surpassed and that of the teeth nearly equaled by the spines. Hence we must conclude that most of the Paleozoic Sharks were provided with spines.

In regard to the influences which have operated to produce the general disarmament which we find recorded in the life history of the Sharks we can at least imagine a solution of the problem. In my judgment it is simply the supersedure of a useful device by one still more useful; that is, the substitution of attack for defense, of activity and intelligence for mere negative resistance, a change in the mode of warfare, and the disappearance by disuse and atrophy of devices which had become useless and obsolete. I have elsewhere[1] incidentally referred to this question, and have there used the following language, which I venture to quote:

[1] Palæontology of Ohio, vol. 1, p. 266.

Very few living Sharks have dorsal spines, but their abundance in some of the geological formations seems to indicate that they were worn by a majority of the ancient Sharks. The significance of this apparent difference we cannot fully comprehend at present, but it has doubtless an important zoological meaning. The changes in the "habits of good society," as illustrated by our history during the last two centuries, may perhaps help us to explain the phenomenon. A hundred years ago every gentleman wore his small sword, and was so prompt and skillful in its use, that he who was without the weapon or the power to wield it was at a great disadvantage among his fellows. When, therefore, the habit was general, it was necessarily universal; but now a general disarmament has put all members of society on an equality. In reviewing the various phases of armament, offensive and defensive, we find such an infinite variety and so many changes of style, that it almost seems that the caprice of fashion ruled the world in former times as now; but all this diversity was doubtless controlled by profound physiological laws. There can be little question that both utility and beauty took part in producing the varied results; that sexual selection and the survival of the fittest combined to produce the variety we see. A curious parallelism is discoverable in the changing styles and in the effectiveness of contemporaneous offensive and defensive armor, and we see that all through the ages the same contest has been maintained that is now going on between improved projectiles and plate armor.

In the Middle Ages, for defense against the spear, sword, and mace, chain, scale, or plate armor was adopted, and the latter was finally made so nearly impenetrable, that it rendered the wearer almost invulnerable; but such a suit of armor was so heavy as to prevent all free and rapid movement, and indeed in some cases to render it difficult for an overthrown warrior to rise from the ground. The introduction of fire-arms rendered scale or plate armor practically useless, and it was speedily abandoned. This change also involved the adoption of a new system of tactics, and celerity of movement with the musket, bayonet, and artillery has become the important factor in modern warfare. So in the history of the Elasmobranchs, we find that the negative defenses of spines and dermal tubercles have been subordinated to the teeth, the chief organs of attack; the cutting and piercing succeeding the crushing teeth, *Otodus*, *Carcharodon*, *Lamna*, and *Odontaspis* superseding the Cestracionts, *Psammodus*, *Orodus*, *Cochliodus*, etc.

The Placoderms, the ruling dynasty in the Devonian seas, though clad in armor that made them invulnerable, were heavily handicapped by the defenses which they carried about, and it is therefore not surprising that they were superseded by the swifter and more flexible Sharks and Teleosts.

It is evident that these quick-moving fishes, though powerless to injure the Placoderms by direct attack, were effectually protected by their celerity from their heavily armed enemies or rivals; and as they increased in numbers, they made a desert around their antagonists, and gradually exterminated them by the most powerful of all weapons, starvation.

Section A.—Fishes of the Chemung Group.

The Chemung group includes a series of mechanical sediments, conglomerates, sandstones, and shales, which in my judgment form the true base of the Carboniferous system. They are best developed in western New York, western Pennsylvania, and West Virginia, where they attain a thickness of from 2,500 to 3,000 feet, but thin rapidly and grow fine toward the west, until in central Ohio they are locally wanting, and never attain a thickness greater than about 100 feet. In Illinois this sheet of land-wash is represented by the Kinderhook group, clay and fine sand mingled with calcareous matter and having no considerable thickness.

The fossils of the Chemung are marine, and yet the formation contains no limestone, as the proportion of land wash to organic material was greatly preponderating. It is evidently a shore deposit laid down along the coast of the Alleghany belt of land during a period of subsidence. This subsidence is proved by the fact that the mass is ripple-marked from top to bottom, many of its layers are sun-cracked, bored by annelids and strewed with sea-weeds, like so many other sea-beaches. At numerous localities these evidences of shore conditions may be found running through 2,000 feet or more of beds which must have been successively at the sea level. The sea rose and fell upon this, and hundreds of streams were busy for ages bringing down from the high lands sand, gravel, and clay, which seem to have filled the basin about as fast as its bottom sank. Along this old shore line some of the gravel beds were composed of very coarse material, such as could not have been transported far from its place of origin, which was the belt of high lands now represented by the Blue Ridge. As we learn by faults, 20,000 feet or more of rock were taken from these high lands to make the strata which were forming in the interior basin.

We have seen that the Devonian rocks were deposited in a hydrographical basin, in which the water deepened until, over a large area, a sheet of unusually pure limestone (the Corniferous) was deposited; then the sea began to retire, its outline contracted, and in shallower water, where the land-wash exceeded in quantity the organic matter, the bituminous and earthy shales of the Hamilton were laid down. Finally the Devonian sea was drained away and its bottom became dry land. But not for long. The flood soon returned as the Carboniferous sea, which caused a wide-spread and long-continued inundation; but the water never came to be deep and pure enough to form limestones in New York or along the Alleghany belt. There the Chemung, Catskill, and Waverly were deposited, all land-wash with ripple-marks from top to bottom. While the mechanical beds were being thus deposited along the shore, in the central portion of the interior basin limestone was precipitated, until in Kentucky and southern Illinois it was more than a thousand feet in thickness. The western geologists have divided this limestone into four parts:

1. Chester limestone.
2. St. Louis limestone.
3. Keokuk limestone.
4. Burlington limestone.

The edge of this calcareous sheet now reaches northward to the middle of Ohio and eastward into Pennsylvania and West Virginia. As we examine its boundaries we find that only the Chester group is there represented, but going southward the lower members are seen to come in successively beneath the Chester, until in central Kentucky all are present. This means a gradual subsidence of the land or rise in the sea level, so that the area of pure water was constantly widening. Ultimately it reached beyond the present margin of the limestone, which has been considerably removed and cut up by erosion.

The time occupied in the formation of the Carboniferous limestone was enormous, since it sufficed for the accumulation of more than 1,000 feet of calcareous sediments formed by millions of generations of mollusks, foraminifera, and other lime-secreting animals; each of which made its contribution of shell or skeleton to the mass. During all this time shore waves, rains, and rivers were eroding the land and filling in the adjacent portions of the sea-basin with land-wash. But the progress of events was not uni-

form; the sea advanced and retreated many times, laying down now sheets of gravel (the ruins of the quartz veins of the eroded land), now sand (finer fragments of the same), and again shales, of which the materials were supplied from the argillaceous rocks and were deposited in deeper water.

From these facts it will be seen that the Carboniferous limestone and the Chemung rocks were largely synchronous, but the conditions under which they were deposited were different, and few of their fossils are the same. In the turbulent water of the shallows and in the bays and estuaries groups of mollusks and fishes lived which were quite different from those of the open sea. In the latter Sharks predominated and thickly strewed the sea bottom with their spines, teeth, and dermal tubercles. Along the shores were also Sharks, but with them greater numbers of scaled and plated Ganoids. The remains of these fishes are found dismembered, scattered, often rolled and worn in the sandstones or conglomerates. In the Berea grit of the Waverly we not unfrequently find entire fishes; small tile-scaled Ganoids washed upon the old beach and buried in the sand; in the Chemung nothing but fragments have yet been obtained, the plates, generally broken, of Placoderms, *Dinichthys*, *Holonema*, etc., the spines of Sharks, especially *Ctenacanthus*, the scales of *Holoptychius*, and the detached palate teeth, often rolled to pebbles, of the Dipnoans, *Ctenodus* and *Heliodus*.

From what has been said of the physical history of the Chemung group it is evident that it marks a great break in the order of nature in the eastern portion of the North American continent, and that it is the record of a period of subsidence which succeeded a long interval of progressive elevation, during which the Hamilton group was laid down. We have also seen that the ocean into which the materials composing the Chemung and Waverly were washed was the Carboniferous ocean, and that in its deeper portions the Carboniferous limestone was forming at the same time that the great banks of sand, gravel, and clay of the Chemung and Waverly were accumulating in the shallower parts.

Only an imperfect view has yet been obtained of the very rich fish fauna of the Chemung group. Nothing was known of it, indeed, until about 1860, when Mr. Andrew Way, of Franklin, Delaware County, N. Y., discovered some bones and teeth of fishes in the Chemung rocks near his

place of residence. These attracted the attention of Prof. Edward Orton, through whom I received a number of interesting things which led me to open a correspondence with Mr. Way. This would probably have resulted in the accumulation of a large amount of new material, but his death arrested the flow of knowledge from that source, and as he alone knew the localities that had furnished his specimens, the visits of other collectors to that region have been for the most part fruitless.

About ten years since Mr. F. A. Randall discovered in a Chemung conglomerate at Warren, Pa., a considerable number of the teeth and bones of fishes, though generally in a rolled and broken condition. Subsequently a collection of similar character was made at the same place by Mr. Charles E. Beecher, of Albany. Both these gentlemen have been kind enough to send their collections to me for examination, and I have described from them a number of new species.

Mr. Andrew Sherwood, of Mansfield, Tioga County, Pa., who has been from childhood an enthusiastic collector of fossils, has from time to time obtained fish remains from the Chemung of that neighborhood; one of these forms the type of the genus *Heliodus*, to which further reference will be made. Finally Mr. A. T. Lilley, of Le Roy, Bradford County, Pa., has found many fish remains in the Chemung group near his place of residence, and among them the representatives of several new genera and species, of which brief descriptions are given on the succeeding pages.

Order DIPNOI.

Genus HELIODUS, Newb.

Many years since Mr. Andrew Sherwood discovered in the Chemung rocks of Tioga County, Pa., the palate tooth of a fish which I have described[1] and made the type of a new genus, to which I gave the above name.

P. J. Van Beneden describes[2] the palate tooth of a fish which is without doubt generically identical with that found by Mr. Sherwood, but it is very much larger, the former being less than two inches in diameter, while the

[1] Palæontology of Ohio, vol. 2, p. 62. [2] Bull. Royal Academy Belgium, 2d series, vol. 27, p. 385.

latter is eight inches. M. Van Beneden considered his specimen as generically identical with a fish earlier described by M. de Koninck and himself,[1] and which was made the type of a genus called by them *Palædaphus;* but in my notice of *Heliodus* I pointed out that the two fishes differed in this, that while in *Palædaphus* the teeth were separated, forming a pair like those of *Ctenodus*, *Dipterus*, and *Ceratodus*, in *Heliodus* they are united to form a single symmetrical, rounded, or semicircular triturating organ.

In an excellent article on *Dipterus*, *Palædaphus*, etc., published by Dr. R. H. Traquair,[2] the opinion is advanced that the two species of *Palædaphus* (*P. insignis* and *P. devoniensis*) should not be separated, and that the genus *Heliodus* can not stand. From this opinion, however, I am compelled to dissent, and to maintain the integrity of *Heliodus* as a genus distinct from all its associates in the family of the Ctenododipterini (*Dipterus*, *Ctenodus*, *Ceratodus*, and *Palædaphus insignis*), for the reasons given in my description of the genus in the Palæontology of Ohio, viz: In all the genera enumerated the teeth consist of a pair of triturating plates in each jaw, the lower pair seated on the splenial bones, the upper on the palato-pterygoids. In *Heliodus*, on the contrary, the dental apparatus of the upper jaw (we know nothing yet of the lower) consisted of a single dental plate, which represents the two teeth of the other genera united in one solid piece. This seems to me to be a character which has generic value. The specimen upon which my description is based remains unique, and is in the cabinet of the School of Mines, Columbia College.

Heliodus Lesleyi, Newb.

Plate XVIII, Fig. 3.

Heliodus Lesleyi N.; Palæontology of Ohio, vol. 2, p. 64, pl. 58, fig. 18.

Upper dental plate rounded or hippocrepiform, one and a half inches in length and breadth; triturating surface more than a half circle, highest in the center, where it forms a broad smooth boss; from this radiate eight tuberculated ridges, four on either side of the median line, which is marked by a deep and smooth furrow. The ridges on each side differ among them-

[1] Bull. Royal Academy Belgium, 2d series, vol. 17, p. 143.
[2] Annals and Magazine Nat. Hist., July, 1878.

selves, but are symmetrical with those on the other side, the lateral ridges being shortest and bearing several tubercles, while those which border the central furrow have but a single tubercle at the extremity of each. On both sides of the central boss the crown of the tooth is worn in a shallow, rounded depression by the opposing teeth of the lower jaw. The posterior margin of the crown is nearly straight, and is slightly crenulated at the center. It is bordered laterally by a sloping surface, which extends downward and backward about four lines and expands to form low, wing-like projections. This portion of the tooth was doubtless covered with integument.

Formation and locality: Upper Chemung rocks; northern Pennsylvania. Collected by Mr. Andrew Sherwood.

Genus DIPTERUS, Ag.

On the following pages a number of species of the fan-shaped palate teeth so common in the Devonian and Carboniferous rocks of the Old World are described as species of *Dipterus*. Until recently the group of fishes which they represent was unknown on this continent, and even when the first volume of the Palæontology of Ohio was published their paucity was remarked upon as strange and inexplicable. A few years, however, have made quite a change in the aspect of the problem, as a large number of teeth which clearly belong to the group of fishes which Pander called Ctenodipterines have been obtained from rocks of several different systems; for example, from the Jurassic of Colorado, the Permo-Carboniferous of Indiana, the Carboniferous of Ohio, and from the Chemung and Catskill of Pennsylvania and New York. All these have the same general form and structure, and are so much alike that it is difficult if not impossible to separate them into generic groups. The teeth from the higher horizons are without tubercles on the ridges, while in the Carboniferous and Devonian they are often conspicuously marked in this manner; but there are smooth species in the older as well as in the newer rocks, and they cannot be grouped by any geological lines. By convention those found in the Jurassic, Triassic, and Permian have been called *Ceratodus*, those in the Carboniferous *Ctenodus*, and those from the Devonian *Dipterus*. The experienced

eye will easily discover differences in the groups which are arranged stratigraphically, a predominating type of form or markings associating those of the Devonian with each other, and separating them in a rough way from those of the Carboniferous age. Still, the type which is predominant in the Carboniferous occurs in the Devonian, where may be also found as exceptions the smooth-ridged species of the Mesozoic. That there were strongly marked differences between the fishes that carried teeth so much alike is quite certain, for the group designated by the name of *Dipterus* is so abundant and so well preserved in the Devonian rocks of Scotland that its entire structure has been fully made out, and we find that it was a fish having a tessellated cranium, the palate teeth already described, and a fusiform body covered with strong, enameled, punctate scales. In the Carboniferous and still higher strata, on the contrary, the fishes which carried the fan-shaped dental plates must have been somewhat differently constituted, for neither in the Old nor in the New World has anything like the complete form of the fish been made out. In the lagoons of the coal-marshes of England and Ohio, where the circumstances were favorable for the preservation of even delicate structures, the teeth, usually dismembered, but occasionally attached to the palato-pterygoid and the splenial bones, and portions of the tessellated cranium, were the only parts preserved; while, as yet, in the higher strata nothing but the teeth have been found. This is, however, an indefinable difference, and much more material than we yet possess must be obtained before we can satisfactorily coordinate the fossil Dipterine fishes among themselves or demonstrate their collective or individual relations to the living *Ceratodus*. This has been attempted by Huxley, Gunther, Miall, Traquair, and others, but further than demonstrating the wide differences in structure between the Devonian and Carboniferous Dipterines and the living *Ceratodus* their labors have thrown little light upon the classification of the various representatives of this great genetic line of fishes. For the present, then, it is safer not to attempt to classify accurately the similar teeth of *Dipterus*, *Ctenodus*, and the fossil *Ceratodus;* but, as others have done before us, we now provisionally class all the older Dipterines as belonging to the genus *Dipterus*, the Middle and Upper Carboniferous species as *Ctenodus*, the Triassic as *Ceratodus;* but it would be quite impossible to

give any satisfactory generic definitions to these different groups. In time more material will doubtless make easy what is now impossible.

The teeth here described as new species of *Dipterus* are chiefly from a bone bed in the Chemung conglomerate in northwestern Pennsylvania. In this conglomerate nothing is well preserved but the dense palate teeth of these fishes, and even these are sometimes rolled into rounded pebbles; yet we occasionally find ganoid scales and those that probably clothed the fishes to which the teeth appertained. In this formation, generally classed as Upper Devonian, but in my judgment more properly considered as the base of the Carboniferous, a careful search will undoubtedly bring to light a large number of fish remains which cannot fail to be of great interest. What we know of them now is almost solely due to the efforts of Mr. F. A. Randall and Mr. C. E. Beecher, who, while much occupied with business duties, found time to observe and collect with discrimination and success.

It will be noticed that a very important addition has been made to the list of Dipterine fishes before known by the discovery by Mr. Frank Wagner of a magnificent species of *Ctenodus* in the Cleveland shale (Lower Carboniferous) at Cleveland, Ohio. This tooth, which is fairly shown in Pl. XXVII, Fig. 30, has been named *C. Wagneri*, in recognition of the sharp-eyed industry of Mr. Wagner, who has obtained from this formation and locality, before considered barren, an interesting series of fish remains.

DIPTERUS (CTENODUS) NELSONI, n. sp.

Plate XXVII, Figs. 19, 20.

Teeth ovoid or triangular in outline, one inch to one inch seven lines long, one-half inch to one inch in width; crown marked with seven strong, acute, radiating ridges, somewhat waved or obscurely tuberculated. The anterior margin is formed by the strongest of these ridges, the others diminishing in size posteriorly. Though usually seven in number, the rudiment of an eighth is sometimes seen at the back end.

The teeth of this species will be at once distinguished from all others described by their strong subacute ridges, of which the edges are highly polished; sometimes quite plain, especially in large and old teeth; in those

which are smaller and less worn undulated, and almost but not quite tuberculated.

The best specimen in my possession was received from Prof. E. T. Nelson, of Delaware, Ohio, to whom the species is dedicated.

Formation and locality: Chemung group; Warren, Pa.; where it has been obtained by Mr. F. A. Randall and Mr. Charles E. Beecher.

DIPTERUS (CTENODUS) FLABELLIFORMIS, n. sp.

Plate XXVII, Figs. 21, 21a.

Teeth triangular in outline, about one inch in length, those of the upper jaw nearly as wide as long, forming an equilateral triangle; those of the under jaw twice as long as wide; crown remarkably flat; the upper teeth sometimes slightly concave, those of the lower set gently arched; surface marked by eight or more radiating ridges, which continue nearly or quite to the interior angle; the anterior ridges strongest; the middle and posterior ones set with rounded obtuse tubercles.

Though having a general resemblance to some of the teeth described and figured by Pander and Agassiz, there are none which correspond closely with these in form and tuberculation.

Formation and locality: Chemung group; Warren, Pa. Collected by Mr. Charles E. Beecher and Mr. F. A. Randall.

DIPTERUS (CTENODUS) LEVIS, n. sp.

Plate XXVII, Figs. 22, 23.

Teeth triangular or oblong in outline, one inch six lines in length by eight lines in width; strongly arched; ridges very few, four or five in number, all smooth, and, like the central portion of the crown, highly polished. The ridges are relatively short, though high, all the central portion of the tooth being plain.

Of described species this most resembles *Dipterus glaber* Pander,[1] but in that species the ridges are acute, while in the teeth under consideration they are remarkably flattened.

[1] Die Ctenodipterinen der devonischens System, p. 29, pl. 7, fig. 10.

Formation and locality: Chemung group; Warren, Pa. Collected by Mr. F. A. Randall.

DIPTERUS (CTENODUS) MINUTUS, n. sp.

Plate XXVII, Fig. 26.

Teeth small, two to five lines in diameter; ovoid or oblong in outline, gently arched, inner angle of crown smooth; two-thirds of the outer surface occupied by five to seven divergent tuberculated ridges.

These little teeth might be supposed to be simply those of the young of some of the larger species with which they are associated, but their form and markings are such as suffice at once to distinguish them. Aside from their small size they differ from the teeth of *D. Nelsoni*, which they most resemble, in having the ridges strongly tuberculated, while in the larger species they are without tubercles. *D. flabelliformis* is much flatter, with a larger number of ridges, and these more obtusely tuberculated, while in *D. levis* the teeth are of quite different form, and the ridges are without tubercles. Hence we are compelled to regard these as the teeth of a small but well marked species of *Dipterus*, and one which resembles more than its associates the teeth of the Carboniferous genus *Ctenodus*, in many of which the ridges are almost equal in size and divergence, and are composed of closely set tubercles that terminate above in sharp points deflected outward. To these the teeth before us are quite similar, and illustrate what has been said in the notes on the genus, of the impossibility of drawing any sharp line of demarkation between *Dipterus* and *Ctenodus*.

Formation and locality: Chemung conglomerate; Warren, Pa. Collected by Mr. F. A. Randall.

SPHENOPHORUS, nov. gen.

Of the fish to which I have given this name only a clavicle is yet known to me; this is a flattened bone, six inches or more in length by one and a half inches in width at the middle, narrowing to either end; the anterior margin strongly reflexed; the exterior surface is marked by many rows of relatively large arrowhead-like tubercles, closely set one behind the other, the points directed forward.

This strong and elegant ornamentation differs so much from that of any other known fish, that it will serve to identify even the smallest fragment; but until some other portions of the fish shall be discovered it will be impossible to speak positively in regard to its relations. It seems probable, however, that it was a Crossopterygian Ganoid, having affinities with *Holoptychius* and *Onychodus.* The cephalic bones of the latter genus are covered with somewhat triangular appressed tubercles, which I have compared to double cones flattened down on their sides. Some of the bones of *Sauripteris* also exhibit a style of ornamentation closely allied to this.

SPHENOPHORUS LILLEYI, n. sp.

Plate XX, Fig. 15.

The very imperfect generic description given above is based on a single specimen sent me by Mr. A. T. Lilley, of Le Roy, Bradford County, Pa. It was procured from the Chemung rocks in the vicinity, and formed part of a large collection of fish remains which he has obtained from the Chemung and Catskill formations. The arrowhead ornamentation is so peculiar, that it will be immediately recognized wherever seen. It has seemed best, therefore, to give a name to the fish it represents, since it is certain that it will be hereafter met with by those who are collecting the fossils of the Chemung. A more complete description must wait the discovery of more material.

HOLONEMA, nov. gen.

(*Holos*, all; *nema*, thread.)

A Placoderm fish of medium size, having the body inclosed in armor made up of polygonal plates, of which the external surface is entirely covered by radiating raised lines of enamel. The central plate of the plastron is coffin-shaped, pointed before, broadest near the anterior end, where the sides are produced into prominent lateral angles; from this point backwards it narrows to a truncated end, which is half as wide as the greatest breadth. In the only species yet known this plate is about eight inches in length by four inches in breadth. Numerous portions of other plates have been for a long time in my collection, but none are sufficiently complete to enable me to

reconstruct the defensive armor. Probably the central plate of the plastron was surrounded by four others, as in *Coccosteus* and *Dinichthys.* Of the plates of the upper surface of the body we have as yet little knowledge. Whether the body was protected above by one great dorsal plate, as in *Dinichthys*, or by six or more articulated together, as in *Pterichthys*, we can not say, but some of the plates which have been found may perhaps have been located on the back.

More material will be required before we can decide in regard to the affinities of this fish, but since we have failed to find any trace of a dorsal shield resembling that of *Dinichthys*, the strongest plate in the armor and the most likely to be preserved, we may infer that the protection of the upper side of the body, like that below, was furnished by several overlapping and relatively small and thin plates.

Prof. E. W. Claypole, who described[1] the middle ventral plate of this fish, has referred it with doubt to *Pterichthys;* but this was a much larger fish than any known species of that genus and had a dermal armor composed of plates of different shapes from those of *Pterichthys* and ornamented in a distinct and peculiar way. Many years before Professor Claypole published the notice of his *Pterichthys rugosus* I had received fragments of different plates of this fish and had written a partial description of them, giving to the genus the name now used. Feeling it necessary to separate the genus from *Pterichthys*, I have thought best to retain the name then chosen as expressive of its most striking character, retaining Professor Claypole's name for the type species described below.

Holonema rugosa, Claypole, sp.

Plate XVII, Figs. 1–4.

***Pterichthys rugosus*, Claypole; Proc. Am. Philos. Soc., vol. 20, 1883, p. 664.**

In the Chemung rocks of New Jersey and northern Pennsylvania it is not uncommon to meet with fragments of flat and relatively thin plates of bone, which evidently once formed part of the defensive armor of a Placoderm fish. These fragments are usually covered with an ornamentation

[1] Proc. Am. Philos. Soc., vol. 20, 1883, p. 664.

which consists of raised enameled lines, often simple and parallel, but sometimes broken and somewhat tortuous.

In 1865 I received from Prof. Edward Orton a nearly complete plate of a comparatively small individual belonging to this species. It had been obtained by him from the Chemung rocks of Franklin, Delaware County, N. Y. This was a posterior lateral plate of the ventral series. Subsequently I found in the State cabinet at Albany, New York, numerous fragments of plates marked in the same manner, but none sufficiently well preserved to permit a restoration of the complete outlines. From Mr. A. T. Lilley, of Le Roy, Bradford County, Pa., I have recently received a considerable number of such fragments, several of which are represented on Plate XVII. The largest portion of any plate yet found, except that figured by Professor Claypole, is that represented in Fig. 1, the original of which is now in the geological collection of the American Museum of Natural History. For the privilege of reproducing it I am indebted to the courtesy of Prof. R. P. Whitfield. This is plainly a lateral plate, but whether of the upper or under surface is not certain. That it is a lateral plate may be inferred from its lack of symmetry and the fact that it nowhere shows the beveled margins, indicating overlap, so characteristic of the central plates in this and other related fishes.

The surface markings of the plates of this fish are so peculiar, that they will be recognized wherever found, and it is hoped that the figures now given will prompt collectors to search for material which will permit its complete restoration.

In Fig. 2 I have copied Professor Claypole's photograph, given in the Proceedings of the American Philosophical Society. It is reproduced by photo-engraving, and may therefore be accepted as truthful. It is of about half natural size; the original, of which Professor Claypole has kindly sent me a cast, was not arched, but quite flat; from which, as well as from its form, I infer it was the central plate of the plastron, and to be compared with the lozenge-shaped plate of *Coccosteus;* the ventro-median plate of Owen.

Since the above notes were written I have received from Professor Claypole a cast of another plate of *Holonema rugosa*, said to have been found in the Catskill rocks of Bradford County, Pa. It is a lateral plate, much

like that represented in Fig. 4, but rounded below and with coarser ornamentation, like that of Fig. 3, which is a copy of a portion of a central plate of the carapace, found in the same region, but said by Mr. Lilley, from whom I received it, to have come from the Chemung rocks.

Ganorhynchus Beecheri, n. sp.

Plate XIX, Fig. 2.

Head terminating anteriorly in a massive bony arch, of which the under surface is rounded and covered with a thick sheet of polished enamel, marked with pits of irregular size and distribution, the mouths of calcigerous tubes. Of this bone the anterior face is vertical, the under surface flatly arched from front to rear, the posterior face transversely straight in the middle, on the sides excavated to form two large rounded notches, perhaps the nasal apertures.

This interesting specimen apparently represents the labial margin of the upper jaw; a strong bony arch firmly anchylosed to the head, and covered with polished but porous enamel, forming a powerful dental organ, fitted for crushing mollusks or crustaceans. It is evidently generically identical with, but specifically different from, a peculiar and unique specimen found without label or history by Dr. Henry Woodward among the material inherited by the South Kensington Museum from the British Museum, and described by Dr. R. H. Traquair[1] with the name of *Ganorhynchus Woodwardi.* The resemblances and differences between that specimen and the one before us will be apparent on comparing the figures now given with those which accompany the article referred to.

Dr. Traquair compares his specimen with the nasal extremity of the head of *Dipterus*, and gives apparently good reasons for considering it the labial margin of the upper jaw of a Dipnoan fish allied to *Dipterus*, *Ctenodus*, and *Palædaphus.* It is even possible that both the specimen described by Dr. Traquair and that now under consideration are the anterior and premaxillary elements in the dentition of some species of *Ctenodus;* since the extremity of the head of *Ctenodus* is not known, and the labial margin of the upper jaw in *Dipterus* is so similar.

[1] Geol. Mag., vol. 10, London, 1873, p. 552.

The subject will be further illuminated by reference to the paper[1] of Dr. Traquair on *Dipterus, Palædaphus, Heliodus*, etc., also to Van Beneden's description[2] of *Palædaphus.*

As has been mentioned, the history of the specimen described by Dr. Traquair is unknown, and no evidence is furnished by it of the geological age of the strata from which it came. From its relation to *Dipterus* Dr. Traquair infers that it came from some Palæozoic formation. The discovery of a second species of the genus *Ganorhynchus* in the Chemung rocks of Pennsylvania confirms this conjecture, and renders it probable that this was a wide-spread form in the Devonian and Carboniferous ages. It also furnishes new evidence of the great development of this group of Dipterine Ganoids in the age of fishes.

The tessellated cranium of *Dipterus*, so well shown by Hugh Miller and Pander, has little in common with that of *Ceratodus*, but is remarkably like that of *Ctenodus*, as will be seen by reference to the figure given on another page of *Ctenodus Ohioensis* Cope, half size linear from a specimen in the possession of the writer. As is remarked in the Palæontology of Ohio (loc. cit.), the similarity exhibited in the cranium and dentition of these genera is such, that new characters must be found before they can be satisfactorily differentiated.

In 1858 Pander described the anterior extremity of the head of a fish found in the Upper Devonian rocks of Russia, which, though apparently distinct from *Ganorhynchus*, is evidently closely allied to it. In this the labial margin is flattened to form an arched dental plate, behind which on either side are mammillary teeth increasing in size backward. This fish he called *Holodus*, and he has given[3] a description and figure of it.

Later (1863) Hermann von Meyer published[4] a description of the anterior extremity of the jaw of a fish which he called *Archæotylus ignotus*, but it is evident that he had not seen the description of *Holodus*, for his specimen is generically and perhaps specifically identical with that described by Pander.

[1] Annals and Mag. Nat. Hist., July, 1878.
[2] Bull. Acad. Belg., 2d series, vol. 17, 1864; see also Palæontology of Ohio, vol. 2, p. 62.
[3] Die Ctenodipterinen des devonischen Systems, pp. 38–60, pl. 6, figs. 1–14.
[4] Palæontographica, vol. 11, p. 285, pl. 44, figs. 1–7.

It may seem strange that the muzzles only of *Holodus* and *Ganorhynchus*, disconnected from other portions, should be found in several countries, so that we are left in doubt as to the character of the major part of the head and all the body in these fishes; but it should be remembered that the dental apparatus of most animals is composed of the densest and most durable tissues, and it is therefore very frequently preserved, while all other parts have perished. In many ancient fishes the dentary element of the lower jaw was composed of firm and resistant bone, while the angular and articular portions consisted of cartilage, and have entirely disappeared. In the economy of nature hardness and strength are given to organs where these are necessary and indispensable qualities, while those parts not exposed to violence or wear consist of soft porous bone or even cartilage. This is conspicuously true of the structure of the Elasmobranch fishes, and we find the same thing in a less degree throughout the animal kingdom.

PHYLLOLEPIS DELICATULA, n. sp.

Plate XIX, Fig. 11.

Scales or scutes thin, one inch four lines in length by one inch in width, elliptical in outline; the surface marked with fine lines, which on the sides are parallel, but in the central portion of either end are somewhat confused and reticulate. In the center of the plate the lines are very closely approximated, more widely separated on the sides, and still more so at the ends.

The plate upon which this description is based was evidently very thin, and the markings on it are delicate. In form and ornamentation it exhibits a great similarity to the fossil described by Agassiz[1] and called *Phyllolepis concentricus*. At the same time the pecular style of ornamentation is almost identical with that of *Holonema rugosa*, and I can not but think that these rounded, detached, thin plates were in some way associated with large angular ones, which were united to form a carapace somewhat like that of *Pterichthys*.

[1] Poissons Fossiles du Vieux Grès Rouge ou Système Dévonien (Old Red Sandstone), etc., p. 67, pl. 24, fig. 1.

Agassiz says of the specimens of *Phyllolepis*, "that they are not unfrequently met with in the Old Red Sandstone of Clashbennie, Scotland, but are generally incomplete; often rolled as well as torn." This is also the case with the plates of *Holonema*, and I can not but think they are generically identical.[1]

Formation and locality: Chemung group; Bradford County, Pa. Collected by Mr. A. T. Lilley.

DINICHTHYS TUBERCULATUS, n. sp.

Plate XXXII, Fig. 3.

In the fish beds of the Chemung conglomerate at Warren, Pa., Mr. F. A. Randall and Mr. C. E. Beecher have obtained numerous fragments of the plates of a Placoderm which is closely allied to, if not identical with, *Dinichthys*. Aside from a large number of unintelligible fragments of plates once evidently of considerable size (because they are from one-quarter to one-half an inch in thickness) the greater part of two supra-scapular plates and the anterior half of a dorsomedian are sufficiently well preserved to merit description. The supra-scapular plates have essentially the form of those of *Dinichthys Terrelli*, viz, are trapezoidal, and have a similar though still more prominent condyle projecting from the anterior margin for articulation with the angle of the head Also, as in the larger species of *Dinichthys*, a straight and deeply incised line runs from the base of the articulating condyle to the posterior border, traversing nearly the middle of the plate. The portion of a dorsomedian referred to above also has precisely the structure of that of *Dinichthys*, viz, it is evenly arched in outline posteriorly and carries a strong keel on the under surface which terminates behind in a neck-like process projecting downward. These characters justify me in associating these specimens with the species of *Dinichthys*. They present, however, one character not yet noticed in any other member of the genus, viz, the exposed surfaces of the plates of the head and body were strongly tuberculated. This is a character which has given its name

[1] Since the above description was written I have seen in the collection of M. Max Lohest, of Liege, Belgium, a number of scutes of a small species of *Phyllolepis* apparently identical with this. They were from the Psammite de Condroz, the equivalent of our Chemung group.

to *Coccosteus*, the near relative of *Dinichthys*, and it is therefore not out of place in the latter genus.

In size this fish was comparatively small; the supra-scapular plates are about three inches in length and breadth and nearly half an inch in thickness at the center. Two specimens from the same side, and therefore belonging to different individuals, are of about equal size. The dorsomedian is also very small; it was not more than three inches in breadth and length, judging from the portion preserved. The tuberculation of the surface is relatively coarse, and the tubercles vary much in size and are irregularly scattered. Most of them seem to be hemispherical and plain, but others are more or less pitted and a few are stellate. The great thickness of the plates compared with their area is a striking feature in this fish. In this respect it is quite different from the smaller species of *Dinichthys* from the Cleveland shale—*D. minor*, *D. corrugatus*, and *D. Gouldii.*

This species also occurs in the Psammite de Condroz, near Liege, Belgium.

Onychodus Hopkinsi, Newb.

In the Chemung rocks at Franklin, Delaware County, N. Y., Mr. Andrew Way collected many detached teeth of a species of *Onychodus*, to which I have given the above name. These teeth are generally about one inch in length, conical, acute, and simply curved. Occasionally, however, the point is slightly turned forward, giving a hint of the sigmoidal curve which is so conspicuous a feature in the great species of the Corniferous limestone (*O. sigmoides*). The bases of these teeth are expanded, and it is evident that they rested upon and embraced the arch of bone which supported them; in this respect resembling the denticles of *O. sigmoides*, and differing from those of *O. Ortoni*, in which they are sunk in the substance of the bone as posts are planted in the ground. As in the other species of *Onychodus*, the teeth above described formed a series of six to eight in number, set on a short arched bone, which was embraced in the symphysis of the mandible, constituting a piercing, tearing instrument, such as has no known counterpart in the animal kingdom.

The genus, as far as yet known, is represented only by the three species enumerated above, viz: *O. sigmoides*, from the Corniferous lime-

stone; *O. Ortoni*, from the Huron shale; and *O. Hopkinsi*, from the Chemung. They were all apparently marine, cycliferous Ganoids of large size, probably Crossopterygians, of which the head was covered with a large number of enameled plates ornamented with appressed double cones of enamel, and forming a tessellated pattern most like that of *Polypterus*. The bones of the head seem to have disarticulated readily, for they are always found separated and generally scattered. The cranial structure has never been fully illustrated, but the jaws, teeth, and scales are described and figured in the first volume of the Palæontology of Ohio

It may be remarked in this connection that in the genus *Aspidorhynchus* a detached triangular bone is set in or on the symphysis of the mandibles, serving to complete the arch of the jaw and protect it from rupture.

Holoptychius ? pustulosus, n. sp.

Plate XX, Figs. 11, 11a.

In the Chemung group at Warren, Pa., occur many large, thick, bony scales, of which the generic relations must remain doubtful until more material shall be obtained. These scales are round, ovoid, or elliptical in outline, the largest two inches in the longest diameter, one and a half inches in the shortest. The central portion of the exterior surface carries a considerable number of relatively large, round, scattered tubercles; the margins being plain and smooth. By these characters they will be recognized wherever found, and doubtless in time much more will be known about the fishes which bore them. The specimens now in my hands I owe to the courtesy of Mr. C. E. Beecher, who collected them at Warren, Pa.

Holoptychius granulatus, n. sp.

Plate XX, Fig. 9.

Scales circular or elliptical in outline, one and a half inches in greater diameter; covered portion smooth; exposed portion closely set with fine rounded granules of enamel, which on the posterior margin are arranged in parallel rows; in the center and on the sides are promiscuously aggregated.

These scales are not unfrequently found in the Chemung of northern

Pennsylvania, but as yet they have not been connected with any bones which are decisive of their generic relations. The form and general character is that of the scales of *Holoptychius*, and it is certain that the fish which bore them must be related to, if not connected with, that genus.

HOLOPTYCHIUS TUBERCULATUS, n. sp.

Plate XIX, Fig. 14.

Among the fish remains sent to me by Mr. A. T. Lilley, of Le Roy, Bradford County, Pa., are some scales of *Holoptychius*, which seem to be different from any heretofore described. They are round or elliptical in outline, one inch to one and a half inches in diameter, and have the posterior portion occupied by coarse round or elliptical tubercles. They resemble some of the scales figured by Agassiz[1] and called *Holoptychius giganteus*, but by him these are united with other scales that sometimes reach a diameter of five inches, and are very different from anything we have yet found in America. It is possible that our tuberculated *Holoptychius* was identical with that which carried the tuberculated scales in Scotland, but if both the forms of *H. giganteus* of Agassiz really belonged to the same fish, that was different from ours. If, however, the tuberculated form is a distinct species, it may prove to be identical with ours, and would therefore take the name of *H. tuberculatus*. It will be noticed that the tuberculated scales figured by Agassiz all bear enamel *ridges*, as ours do not; beside this, our tuberculated scales are found in the Chemung, which is a marine deposit, while the Old Red Sandstone, like our Catskill, was formed in fresh water; hence the species are probably all different.

HOLOPTYCHIUS GIGANTEUS? Ag.

Plate XIX, Figs. 15, 16.

In the Catskill rocks at Mansfield, Tioga County, Pa., Mr. Andrew Sherwood has found some detached scales of *Holoptychius* which equal in size and resemble in markings those which were described by Agassiz under the name of *H. giganteus*. Up to the present time only isolated scales of

[1] Mon. des Poissons Fossiles, etc. (Old Red Sandstone), pl. 24, figs. 3, 4, 8.

these great fishes have been found in Europe or America, and it is evident that no satisfactory comparison can be made between them until other parts of their structure shall be known. To stimulate search for further and better material I have thought best to call attention to these great scales found by Mr. Sherwood and give figures of them. It will be seen by reference to these figures that our specimens are so much like those described by Agassiz[1] that no character could be fixed upon which would serve to separate them specifically. I have, therefore, provisionally united them, leaving to those who shall be fortunate enough to find something more than these detached fragments to furnish unquestionable evidence of identity or difference.

Only two species of *Holoptychius* are represented in our collections by portions of the body covered with scales in such numbers as to show the range of size and variation in markings. These are *H. Americanus*, Leidy and *H. Hallii*, Newb. The material permits these species to be fairly well defined. None of the scales are tuberculated, and hence they may be considered clearly distinct from the fishes which bore the tuberculated scales, *H. tuberculatus* and *H. giganteus*? Whether the latter two species do not run together remains to be shown by future observations, but the scales of *H. tuberculatus* occur only in the Chemung, and judging from the specimens we now have are not more than half the size of those I have referred to *H. giganteus.*

Helodus gibberulus, Ag.

Among the fish remains collected by Mr. Beecher at Warren, Pa., are numerous small, polished, pitted teeth, consisting of a tumid, subconical, central dome, with a low, subsidiary tubercle on either side. These teeth I have been unable to distinguish from those received from Professor Agassiz, representing his species *H. gibberulus*, from the Mountain limestone of Armagh, Ireland. Similar teeth occur in considerable numbers in the Waverly, at the Miller farm, on Oil Creek, Pa., and in the Mountain limestone of Illinois and Indiana.

With teeth so small and simple as these it would be unwise to insist on an absolute identity of species, but we may at least say that in our Che-

[1] Mon. Poiss. Vieux Grès Rouge, pl. 24, figs. 2–10. *Gyrolepis giganteus* Ag.: Poiss. Foss., vol. 2, p. 175, pl. 19, fig. 13.

mung, Waverly, and Carboniferous limestones occur teeth that cannot be distinguished from the equally abundant and wide-spread *Helodus gibberulus* of the British Islands.

Cladodus carinatus, n. sp.

In the collections made by Messrs. Beecher and Randall from the fish beds at Warren, Pa., are numerous teeth and impressions of teeth of *Cladodus.* Nearly all these, however, are too imperfect for accurate description. They apparently represent several species, but they are very much decomposed. One small species, however, collected by Mr. Beecher, is better preserved, and is so peculiar, that it deserves special notice. It is less than half an inch in breadth and height, the base narrow, and bearing one central and four lateral cones, the exterior pair larger than the intermediate ones, but all much lower than the central denticle. This carries the characteristic feature of the species in four relatively strong carinations on the flattened surface. Of these the outer two are short and low, the inner two relatively stronger than in any other species known to me.

Cladodus Kepleri, n. sp.

Plate XLIV, Figs. 1, 2; Plate XLV.

Fishes three to six feet long by six to eight inches wide at the pectoral fins; body long-fusiform, as broad as high; upper surface covered with shagreen, composed of fine, apparently plain, tubercles; under surface near head transversely striated; jaws partially ossified; teeth very numerous, half an inch in height and breadth, consisting of one striated median cone with one lateral denticle on either side; pectoral fins oblong, conical, rounded at the extremity, five inches wide by eight to ten inches long, traversed by about twenty strong unarticulated, ossified rays, simple below, forked above; eyes large, capsules bony.

We have in these fishes another illustration of the unusual amount of ossification in the skeletons of certain Carboniferous sharks to which I have referred elsewhere, viz, complete ossification of the rays supporting the lower lobe of the tail in the large selachian found by Mr. Patterson in the

Berea shale at Vanceburgh, Ky., and now in the museum at Frankfort; also the partial ossification of the cranium and jaws of *Diplodus*, as shown by the specimens obtained by Professor Cope from the Upper Carboniferous of Texas and by the writer from the cannel coal of Linton, Ohio. Again, it is shown by the ossification of the rays of the pectoral fins of *Ctenacanthus Clarkii* of the Cleveland shale, and in the ossification of the jaws of *Mazodus Kepleri* from the Berea shale, Berea. Though generally considered as selachians and having certainly strong affinities with living sharks, the bones of the cranium and the jaws of these fishes are better ossified than those of most Cretaceous and Tertiary sharks and than those of the present day; while the vertebral centra, following the common and inscrutable law of progress visible among fishes, have become more and more ossified in later ages

Since the above description was written I have received from Prof. William Kepler a magnificent specimen of this fish, which enables me to make the description somewhat more complete. This specimen consists of the halves of a flattened calcareous concretion, which includes the anterior half of the body, with the under side of the head and pectoral fins very satisfactorily shown. The muzzle is rounded, the mouth terminal, the head eight inches long by six inches wide; the eye capsules are elliptical in outline, two inches in the longest diameter; back of the eye are rounded plates, obscurely defined, which look as though they represented the opercula of the Ganoids and Teleosts. The respiratory slits are faintly indicated, but cannot be numbered; the interval between the head and the pectoral fins is occupied by the remains of a fibrous integument of which the fibers were transverse; the pectoral fins are eight inches long by five inches wide at the base, are very clearly defined, are widely expanded and have a reach of twenty-two inches from tip to tip; the basal cartilages are but obscurely shown. They seem to have formed meta, mesa, and propterygia, but this cannot be asserted without further proof. The structure of the fin was evidently simpler than that of sharks now living, but on the same plan. We see nothing of the axial arrangement called *archipterygium* by Gegenbauer, so common in the ancient Ganoids, and surviving in *Ceratodus*.

Formation and locality: Cleveland shale; Brooklyn, Ohio.

Ctenacanthus Randalli, n. sp.

Dorsal fin-spines twelve inches or more in length by one and a half inches in width at base of ornamented portion; form slightly curved backward, sides compressed, basal portion conical, smooth, or finely striated longitudinally; line of demarkation between ornamented surface and base strongly marked, inclined downward and forward at an angle of 30° with the axis of the spine; ornamented surface near base formed by about forty fine, parallel, subequal, closely crowded ridges on each side of the median line, and these bear small, rounded, closely approximated tubercles.

The basal portion of a large spine, showing about two inches of the ornamented surface, is the basis of the above description. This was obtained from the Olean Conglomerate, two miles northeast of Warren, Pa., by Mr. F. A. Randall. Several much more perfect specimens have been found in that vicinity, but they have been sent to Philadelphia and are not within my reach. Better material will be needed for a complete description; but enough is shown in the specimen now described to prove this spine distinct from any other known. In the character of its surface markings this species resembles *Ctenacanthus tenuistriatus*, Ag. and *Ct. speciosus*, St. J. & W., but differs from both these in its narrower form and the character of the ornamentation of its surface. In *Ct. tenuistriatus* the ridges are separated by spaces as wide as themselves, whereas in the species under consideration they are for the most part contiguous or separated by very narrow furrows. In the former species also the ridges along the anterior border are much wider than on the sides, whereas in *Ct. Randalli* they are of nearly uniform size throughout. The tuberculation in the present species is very simple; rounded papillæ, separated by spaces but little greater than their diameters, are set regularly along the summits of the ridges, while in *Ct. tenuistriatus* and in *Ct. speciosus* the tuberculation consists of transverse ridges, as is most common in the genus.

The general aspect of this spine must have been similar to that from the St. Louis limestone described elsewhere in this memoir under the name of *Ctenacanthus Littoni*, but the ridges are in that species fewer and the tuberculation is much stronger and more crowded.

SECTION B.—FISHES OF THE CATSKILL GROUP.

The Catskill formation took its name from the Catskill Mountains, which are in large part composed of it. It consists of a series of conglomerates, sandstones, and shales, of which the prevailing color is red, and the thickness in southern New York and Pennsylvania is not less than 5,000 to 6,000 feet. The area occupied by the formation is not large. It reaches southward along the Alleghanies into Virginia, but does not pass westward beyond the limits of New York and Pennsylvania. In its lithological characters (all land-wash) and its limited area it resembles the Trias of the eastern United States and the Old Red Sandstone of Scotland, and there are many reasons for believing that, like these formations, it was deposited in a circumscribed body of fresh water.

Aside from the fishes it contains—which are for the most part generically identical with those of the Upper Old Red Sandstone—comparatively few fossils have been found in the Catskill; these are land plants (ferns, *Lepidodendra*, and *Sigillaria*) and fresh water shells (*Anodonta*). The most common ferns belong to the genus *Archæopteris* (formerly included in *Cyclopteris* and *Paleopteris*), which is very characteristic of the Upper Devonian and Lower Carboniferous rocks.

From these facts and others which might be cited we may fairly conclude that the Catskill rocks were deposited in a fresh-water lake, which lay immediately along the west base of the ancient land now represented by the Highlands of New York and New Jersey and their southern continuation, the Blue Ridge. Just how far this lake extended north and south we do not know, but apparently not more than two hundred miles, while its breadth from east to west did not exceed one hundred and fifty. I have elsewhere given my reasons for considering the Chemung group, which immediately underlies the Catskill, as the base of the Carboniferous system. This was not the classification originally adopted by the New York geologists, but since their schedule was made up many new facts have come to light which have led me to adopt the views now presented.

The Catskill also was formerly attached to the Devonian system, but there is no other reason than conservatism for this usage. We know, of

course, that the stream of time flowed steadily on through the geological ages; and we have reason to believe that over vast areas of the earth's surface constant marine conditions have prevailed, and there the stream of life flowed on without break, and the geological record must be without chapters or sections. But from time to time the sea overflowed its banks, and left landmarks which form convenient division lines of history. Such an event occurred at the close of the Hamilton age and the beginning of the Chemung. It seems to me more natural, therefore, to consider the latter the introduction of a new age, the Carboniferous. In regard to the Catskill there is less difference of opinion, and it is now quite generally referred to the Carboniferous age.

The first notice of the remains of fishes in the Catskill group was published by Prof. James Hall.[1] In this paper are figured the scales of a species of *Holoptychius*, considered identical with *H. nobilissimus*, Ag., from the Scotch Old Red Sandstone. It is, however, a distinct though closely allied species, the scales of the American fish being not more than half the size of the Scotch, and having smoother and more continuous enameled ridges than those of the type specimen.[2]

Later (1856) Prof. Joseph Leidy described[3] a number of fish remains from the Catskill of northern Pennsylvania, among others the scales and part of a cranial plate of this fish, to which he gave the name of *Holoptychius Americanus*. Some conical teeth having striated bases and a circular section were also referred to *Holoptychius*, but the relationship is uncertain, inasmuch as they were not found in connection, and it is quite possible that the teeth belong to some other one of the several Ganoid fishes associated with *Holoptychius* in the Catskill rocks. Professor Leidy also referred to *Holoptychius* a scale or plate,[4] of which the exterior surface is covered with tubercles arranged in flexuous and confused lines. This we now know is not a scale, properly speaking, but a dermal plate of a different fish, which has left abundant remains in the Catskill, and which I have considered a species of *Bothriolepis*.

[1] Nat. Hist. New York, pt. 4, Geology, 1843, p. 280, wood cut 130, figs. 1, 2, 3.
[2] Mon. des Poissons Fossiles, etc. (Old Red Sandstone), pl. 23.
[3] Jour. Acad. Nat. Sci., Phila., 2d series, vol. 3, p. 163.
[4] Ibid., pl. 17, fig. 4.

The conical, compressed, ancipital tooth found in the same beds and described[1] by Professor Leidy under the name *Apedodus*, resembles some of the teeth of *Sauripteris Taylori*, and may have belonged to that fish. Professor Zittel[2] includes *Apedodus* Leidy in *Rhizodus*, but no traces of that genus have been found in the Catskill rocks, while detached striated teeth resembling those of *Holoptychius* and *Sauripteris* are not uncommon. I am therefore of the opinion that they should be referred to these genera and not to *Rhizodus*.

Order PLACODERMI.

Genus BOTHRIOLEPIS, Eichw.

A very considerable number of specimens of what is apparently a species of *Bothriolepis* have been found in the Catskill rocks of New York and Pennsylvania; also a less number of fragments of a smaller species in the Chemung group of the same region. They consist for the most part of body plates dismembered and scattered, and the arms in a better or worse state of preservation. The arms are frequently seen articulated with the anterior ventral plate as in *Pterichthys*. Each one is a compressed triangle in section, the base toward the body, the apex turned outward and forming a sharp keel, which is set with prominent enameled tubercles. Usually only the upper three or four inches of this organ are preserved; this part seems to have been a solid and homogeneous rod of cartilage covered with several articulating plates of enameled bone. It rapidly narrows below, and at first sight would be thought to constitute the entire organ, but spliced on to its conical extremity was a sharp and rather slender spine two inches or more in length. This is covered with small articulating plates above and is longitudinally striated below. It carries on the outer edge a series of relatively strong, acute denticles.

The ventral armor of *Bothriolepis* apparently consisted of five plates as in *Pterichthys*, and of these the outer surface is ornamented with vermicular furrows separated by narrower ridges. These furrows are sometimes continuous, sometimes interrupted forming pits of which the bottoms are often

[1] Jour. Acad. Nat. Sci., Phila., p. 164, pl. 17, figs. 5, 6.
[2] Handbuch der Palæontologie, Abtheil. 1, vol. 3, part 1, p. 182.

pierced by minute orifices; in short, precisely the surface markings shown in the figures and descriptions given by Agassiz in his Old Red Sandstone Fishes. The armor of the upper side of the body consisted of a series of polygonal scutes, which have never yet been found in position, and therefore nothing positive can be said in reference to their number and arrangement. In Tioga County, Pa., Mr. Andrew Sherwood has obtained at one locality hundreds if not thousands of these plates of *Bothriolepis Leidyi*, crowded together as though they had been the numerous scales of some relatively large fish. According to Eichwald the body of *Bothriolepis* was covered with scutes, which he supposed to have been arranged in rows like the plates of the sturgeon, and such was the belief of Agassiz; but in the important paper "On the Structure and Classification of the Asterolepidæ," published by Dr. R. H. Traquair in the Annals and Magazine of Natural History for December, 1888, *Bothriolepis* is described as having essentially the same structure as *Pterichthys*, and differing from that genus only by a few minor characters, which render it rather difficult to distinguish them. The material yet obtained in the United States, all of which I have passed in review, is too fragmentary to give much assistance in the settlement of this question; but it is quite certain that where hundreds and thousands of fragments of the defensive armor of *Bothriolepis* occur, as they do in the Catskill of Tioga County and the Chemung of Bradford County, Pa., individuals ultimately will be found in so good preservation as to harmonize the diverse views which have been entertained in regard to these singular fishes.

One remarkable feature in *Bothriolepis* is the peculiar joint by which the pectoral spine articulates with the body, and which shows essentially the same structure that we find in the Siluroids of the present day.

Most persons are familiar with the complicated and effective articulation of the pectoral fins in our catfishes (*Amiurus*). The arched head of the spine moves freely in a groove through an arc of about ninety degrees, and is protected by guards, which prevent lateral motion and fix it firmly at the will of the fish at the point of greatest possible extension from the body. In some of the Siluroids it is impossible to separate the spine from its socket without fracture, even when the soft parts have all been removed. The

spine is flattened, and when extended its edge is turned forward so as not to impede the passage of the fish through the water. As the fin is folded it turns, presenting its flat side and the web of the fin to the water, to facilitate propulsion. In *Bothriolepis* the pectoral spine is also flat and must have revolved in the same way; the articulation was also very firm, and the spine is usually found in connection with the plates or bones which formed the socket.

The peculiar laminated structure of the articulating head of the pectoral spine in *Pterichthys* and *Bothriolepis*—figured though not mentioned by Agassiz and Pander—seems to have been precisely the same as in *Plecostomus, Phractocephalus,* and other plated Siluroids, and is visible in *Pimelodus.* This strengthens the suggestion of Professor Huxley, that the Placoderms are genetically related to the plated Siluroids of our present day. The points of similarity which led him to suspect a relationship between them were mainly in the defensive armor and the structure of the shoulder girdle. To these I now add the striking analogy in mechanical arrangement and identity of microscopical structure in the pectoral spine and its articulation. It seems impossible that all these coincidences could have been produced by anything but inheritance.

Prof. E. D. Cope, in the American Naturalist for March, 1885, proposes a new theory of the zoological relations of *Pterichthys,* namely, that it was a Tunicate allied to *Chelyosoma.* With the abundant proofs of the relationship of *Pterichthys* to *Bothriolepis, Aspidichthys, Holonema,* and the other members of the family *Pterichthidæ,* it is evident they must be grouped together, and the ichthyic character of *Pterichthys* is settled by the preservation in many instances of a tail covered with scales connected with the carapace. It is true that in the Canadian species of *Pterichthys* (*P. Canadensis,* Whiteaves), of which so many individuals have been found in excellent preservation, no evidence of a caudal extension of the body has been seen; probably for the reason that it was not scaled, but simply covered with a skin, like *Polyodon* among the generally plated *Chondrostei.*

Two species of *Bothriolepis* seem to have left their remains in the Chemung and Catskill rocks of New York and Pennsylvania; one, that just referred to, from the Catskill, and another with smaller and more finely

marked, but in other respects similar, plates in the Chemung. Of these species I append the diagnostic characters.

Bothriolepis Leidyi, n. sp.

Plate XVIII, Fig. 2; Plate XX, Figs. 1–5.

Form and dimensions of the body unknown; surface covered with a number of angular, closely approximated, enameled plates, which are elliptical, subtriangular, or oblong in outline, and from one and a half to three inches in length by one to two inches wide; the exterior surface is wholly occupied by a series of vermicular furrows or lines of hopper-shaped connecting pits, which are often pierced or punctate at the bottom; this surface is also ornamented by three incised lines, which diverge from the center to the middle respectively of the posterior and the postero-lateral margins; the inside of most of these plates carries a prominent keel along its central line for two-thirds of its length.

Besides these, the more common form of plates, there are others which are much more highly arched and doubtless covered the lateral surfaces of the body. The head, but imperfectly shown in our specimen, was apparently much like that of *Pterichthys*, viz, was rounded in outline, strongly arched, and was covered with a series of polygonal plates with a dumb-bell aperture in the center. The pectoral organ was also similar to that of *Pterichthys* in form and markings; it was from four to six inches in length, terminating above in a hemispherical smooth head, composed of dense bony tissue, exhibiting a peculiar laminated structure. The proximal element is from one-half to three-quarters of an inch wide, gently curved and rounded or blunt-pointed at the extremity; the surface was formed by a series of angular plates, carrying the same ornamentation as the body plates. The distal portion was a slender spine articulating with or anchylosed to the upper portion, and was doubtless used as an organ of defense. At its base the surface was formed by a number of small plates; toward the summit it is longitudinally striated. The point is sharp, and the outer margin is set with a row of relatively strong, acute, recurved denticles. This spine has been described by Dr. Leidy under the name of *Stenacanthus nitidus.*[1]

[1] Jour. Acad. Nat. Sci., Phila., 2d series, vol. 3, p. 164, pl. 16, fig. 8.

Formation and locality: Catskill group; Mansfield, Tioga County, Pa. Collected by Andrew Sherwood.

BOTHRIOLEPIS MINOR, n. sp.

Plate XX, Fig. 6–8.

Body plates elliptical or angular in outline, from half an inch to one and a half inches in longest diameter, many hexagonal, but longer than broad; under surface often carrying a strong keel along the central line; the outer surface covered with fine, closely crowded, vermicular furrows, and also by divergent lines passing from the center to the middle of the three posterior margins.

This species is distinguished from the preceding one by the smaller size of the plates and the very much finer ornamentation of the surface. The material which I have representing it includes no portion of the head or arms, and therefore no extended comparison can be made. The two species, however, occur at different horizons, and are represented by hundreds of plates, all of which may be distinguished at a glance by the difference in the surface ornamentation. A species similar to this, and perhaps identical with it, has been found by M. Lohest in the Psammite de Condroz, near Liege, Belgium.

Formation and locality: Chemung group; Le Roy, Bradford County, Pa. Collected by Mr. A. T. Lilley.

Order CROSSOPTERYGIDÆ.

Genus SAURIPTERIS, Hall.

In his notice of the Catskill fishes of New York[1] Professor Hall describes a portion of the shoulder girdle, a pectoral fin, and some scales of a large fish found near Blossburgh, Pa., to which he gave the name of *Sauripteris Taylori.* Having recently had an opportunity, through the courtesy of Prof. R. P. Whitfield, of examining the original specimens figured by Professor Hall, and many others obtained with them, now forming part of the collection of the American Museum of Natural History, I am able to con-

[1] Nat. Hist. New York, pt. 4, Geology, p. 282, pl. 3.

firm the conclusions of Professor Hall in regard to the specific, if not generic, distinctness of this fish, and can add something to his description.

The pectoral fin figured by Professor Hall is too imperfect for satisfactory study, but it was probably in part covered with scales (lobed) like the paired fins of *Holoptychius*. The scales have the same general character with those of that genus; that is, they are circular, subquadrate, or elliptical in outline, from one and a quarter to two and a half inches in greatest diameter, the covered portion beautifully reticulated with large elongated meshes, the exposed portion thickly set with fine conical or rounded granules, generally without linear arrangement. The external surfaces of the bones composing the pectoral arch, as well as those of the head, are ornamented with short, strong, flexuous, enameled ridges, and rounded or triangular tubercles. The jaws are set with conical, compressed, striated teeth, resembling that described by Professor Leidy under the name of *Apedodus*. The external surface of the dentary bone is for the most part occupied with fine granulations like those of the scales, but more widely separated. Toward the lower border the ornamentation is coarser and similar to that upon the clavicles; the surface of some of the head bones is granulated like the scales.

The general structure of *Sauripteris* is essentially that of *Holoptychius*, and it would not be at all surprising if the discovery of more complete material would compel the union of the two genera.

Holoptychius Americanus, Leidy.

Plate XIX, Figs. 12, 13.

The scales to which the above name was given by Dr. Leidy had been previously regarded as identical with those of *Holoptychius nobilissimus*, Ag., of the Scotch Old Red Sandstone. This is not surprising, for some of the scales from the caudal portion of the body of *H. nobilissimus* are undistinguishable from these in size, form, and markings; but, as any one can see from a glance at the magnificent plate given of this species by Agassiz,[1] most of the scales have a reticulated marking quite different from any yet found in this country. Hence it is certain that Dr. Leidy's species is not

[1] Mon. des Poissons Fossiles, etc. (Old Red Sandstone), pl. 23.

identical with *H. nobilissimus.* Among Agassiz's figures of the scales of *Holoptychius* in his Old Red Sandstone Fishes, are two very different kinds, which he combines, probably because he found them running together, under the name of *H. giganteus.* One[1] of these has almost precisely the ornamentation of the scales of *H. Americanus;* that is, a series of strong, flexuous, sometimes inosculating but subparallel ridges running from the interior to the posterior border. Another form, there represented by figs. 3, 4, and 8, has most of the ornamented surface occupied by coarse, rounded tubercles; the middle portion only carrying short ridges mixed with tubercles. It is evident that we have here two strongly marked varieties, which without any great stretch of the imagination could be considered as distinct species. This latter supposition is favored by the fact that in some cases the ridged type of scale referred to above seems to have covered the entire body, and I have seen similar scales from the Scotch Old Red Sandstone nearly three inches in diameter. Precisely such scales as these, but never more than half as large, are common in the Catskill rocks, and represent Dr. Leidy's *H. Americanus.* Larger scales from the Chemung, nearly two inches in diameter, have a coarser ornamentation, consisting of mingled ridges and tubercles, and these I have made the type of a new species *H. tuberculatus.*

Holoptychius Hallii, n. sp.

Plate XX, Figs. 10–10ª.

Fishes, two to three feet in length by six to eight inches in width; head unknown; pectoral fins conical in outline, five inches long by two inches wide at base, pointed, acute, strongly lobed; central portion three inches long by half an inch broad, covered with scales and surrounded on all sides by a margin of fin rays; ventral fins midway between pectoral and anal; two dorsal fins, first dorsal opposite space between ventrals and anal, second dorsal slightly behind anal, both of these reaching back to caudal; caudal fin broadly triangular in outline; posterior margin nearly vertical, arched, about five inches in height in a fish 2 feet long; lower lobe very broad; prolongation of body turned upward and fringed on the upper side with rays about one inch in length; scales circular in outline, closely imbri-

[1] Mon. des Poissons Fossiles, etc. (Old Red Sandstone), pl. 24, fig. 2.

cated over the entire body; on the anterior and middle portions one inch and at base of caudal fin one half inch in diameter; exposed portion occupied by broad, flattened, striated, radiating, or reticulated ridges; on the sides and anterior portion of the body the scale-markings are finer, more numerous, and parallel.

Only one specimen of this fish is yet known. It was found near Delhi, N. Y., and was presented many years since to the State cabinet by Rev. Mr. Fitch. This specimen wants the head, but in the two pieces which represent it nearly all of the body from the base of the pectoral fins is shown. The form is in a general way similar to that of the restoration of *Holoptychius* given by Huxley in his essay upon the fishes of the Devonian epoch,[1] but the body is less symmetrically narrowed posteriorly and the extension of the scaled portion is abruptly turned upward at the base of the caudal fin. All of the fins are also broader and more rounded than in the figure cited. The ornamentation of the scales is in general similar to that of several described species of *Holoptychius*, especially that of *H. nobilissimus* and *H. Murchisoni*, but no portion of the surface bears granulations or tubercles, and the flattened ridges are elaborately ornamented with waved and inosculating thread-lines. The scales seem to have been smaller and thinner than those of *H. Americanus*, which are so common in the Catskill rocks, and the surface marking is less strong and parallel.

The type specimen of this species is in the State Museum at Albany, where it will serve as a standard of comparison with other remains of fishes which are likely to be gathered in considerable numbers from the Catskill rocks To the courtesy of Professor Hall, the director of the museum, I am indebted for an opportunity of examining and describing it, and I take pleasure in attaching his name to the only species of which any considerable portion of the body has yet been obtained in North America.

Holoptychius ? radiatus, n. sp.

Plate XX, Figs. 12–14.

Body two feet or more in length, fusiform, covered with relatively small, round, or elliptical highly ornamented scales. Of these the covered

[1] Memoirs Geol. Survey United Kingdom, Decade 10, 1861, p. 5.

portion is smooth, while the exposed part, forming from one-third to one-half the area, is occupied by a series of sharply defined thread-like ridges radiating from the central point. These ridges vary from ten to fifteen in number; are sometimes all simple and nearly straight; more frequently some of them are dichotomously forked.

Scattered scales of this fish are not uncommon in the Catskill rocks, but no entire specimen has yet been found. Whether this really belongs to the genus *Holoptychius* remains to be proved, but it was evidently a closely allied Crossopterygian.

The size, form, and markings of the scales are perhaps more like those of *Glyptolepis* than those of most species of *Holoptychius*, but we have as yet no evidence that *Glyptolepis* ever inhabited the waters of North America. This question will doubtless be solved by future discovery.

Glyptopomus Sayrei, Newb.

Plate XVIII, Fig. 1.

Glyptopomus Sayrei, Newb.: Ann. N. Y. Acad. Sci., vol. 1, p. 189.

Fish fusiform, about two feet in length by five inches in diameter; head triangular in outline, five inches in length and breadth; cranial plates unknown; under side of the head covered by two large sigmoidally elliptic jugular plates, bordered by a row of five (?) lateral jugulars, of which the anterior is linear in outline, broadest behind; the middle three are rhomboidal; the posterior is spatulate and the largest of the series; the pectoral fins are elliptic in outline, narrow at the base, which is without fin rays; central portion covered with scales and bordered by a margin of rays that become longer toward the extremity; posterior fins unknown; scales rhomboidal or quadrangular, smooth beneath, strongly marked on the outer surface with pits or short, curved, vermicular furrows divided by sinuous ridges.

The only specimen of this fish yet found was taken from a quarry on the Susquehanna River, near the mouth of the Mehoopany, which supplied the stone for a dam on the former river. It was procured by a railroad engineer, from whom it passed into the hands of Mr. Robert H. Sayre, and

was by him placed in the cabinet of Lehigh University. It was evidently derived from the Catskill group, and represents a genus and species not before met with in America.

Only the under surface of the head and the anterior half of the body are shown in the specimen referred to above. This displays very well the plates which cover the under side of the head, the pectoral fins, and the scales of the under surface of the body, but leaves the outlines of the cranial plates and the posterior fins to be imagined.

Without more material it is impossible to determine with accuracy the generic relations of this interesting fossil Its affinities are evidently with *Glyptolæmus* and *Glyptopomus*, and I have referred it provisionally to the latter. The form of the jugular plates, both central and lateral, is almost precisely the same as in *Glyptolæmus Kinnairdi*, Huxley;[1] but the pectoral plates, which are characteristic of this genus, are wanting. In place of these, the scaling of the under side of the body reaches forward and fills the interval between the divergent bases of the jugulars. The form and markings of the scales as well as the ornamentation of the head plates correspond closely with *Glyptopomus minor*, Ag., from Dura Den; and as by the absence of the pectoral plates it appears to be excluded from *Glyptolæmus*, it has seemed to me probable that it belonged to *Glyptopomus*. Professor Huxley gives a figure[2] of a nearly entire individual of *Glyptopomus minor*, in which the head is seen from the under side. This fish is about fourteen inches long, a little more than half the size of the one before us. The corresponding parts of the body in our fossil and this figure are exceedingly like, and yet there are some notable differences. For example, in Professor Huxley's specimen there seem to be two triangular accessory jugular plates filling the angle between the converging posterior borders of the principal jugulars; whereas in our specimen this angle is occupied by the scales of the under side of the body which run up into it. Again, in the specimen described by Professor Huxley no lateral jugulars are shown, but the state of preservation of the fish is scarcely decisive of their presence or absence. They are present in *Glyptolæmus*, are shown in our fossil, and it has been

[1] Memoirs Geol. Survey United Kingdom, Decade 10, p. 41.
[2] Ibid., Decade 12, pl. 1.

inferred that they were possessed by *Glyptopomus.* Should it prove, however, that they are absent in this genus, we should be compelled to give to our fish a new generic name, and I would call it *Glyptognathus,* in allusion to the conspicuous ornamentation of the mandibles; distinguishing it from *Glyptopomus* by its lateral jugulars, from *Glyptolæmus* by the absence of pectoral plates. To avoid, however, the possible multiplication of synonyms, already sufficiently numerous, I have thought it better to unite it with *Glyptopomus* until the question of the presence or absence of lateral jugular plates in that genus shall be decided by the discovery of more material.

The triangular accessory jugulars in *Glyptopomus minor* might be considered as evidence of generic distinctness from our fish, but until they shall be found in other individuals or other species they cannot be proven to be other than individual or specific characters.

The specimen described above remains up to the present time unique; and yet on the slab on which it lies are portions of two other individuals which, like it, were probably preserved entire. I have made much effort to obtain other specimens; hitherto without success. There is very little doubt, however, that the Catskill rocks will hereafter yield more remains of this fish, as well as of others of which we have up to the present time only very imperfect representation.

Dipterus (Ctenodus) Sherwoodi, Newb.

Plate XXVII, Figs. 3–3[b].

***Dipterus Sherwoodi*, N.; Palæontology of Ohio, vol. 2, pl. 58, fig. 17.**

Teeth one inch in length, triangular in outline; crown marked with three prominent tuberculated ridges, separated by deep furrows somewhat wider than the ridges. The strongest of these ridges forms one side of the triangular tooth. On the angle opposite this side are a few irregular tubercles, but no traces of distinct ridges. The denticles which crown the ridges are somewhat compressed laterally, are rounded, smooth, and blunt at the summit.

This is apparently one of the upper palate teeth of a species of *Dipterus,* and is specially interesting as being the first relic of the genus found on

this continent. It can be readily distinguished from all the species described abroad by the small number of its radiating ridges. This specimen is from the Catskill group of Tioga County, Pa., and was discovered by Mr. Andrew Sherwood, to whom I am indebted for an opportunity of examining it.

Since the discovery of the tooth of *Dipterus Sherwoodi* many others belonging to the same genus have been obtained from the Chemung rocks and are noticed in this paper, but they are distinguishable at a glance from this by their greater number of radiating ridges and smooth or less distinctly tuberculated triturating surfaces. The type specimen of this species is in the cabinet of the School of Mines, Columbia College.

Dipterus (Ctenodus) radiatus, n. sp.

Plate XXVII, Fig. 33.

Another tooth belonging to the genus *Dipterus* has recently been sent to me by Mr. Sherwood. He obtained it from the same formation and locality as that which many years ago furnished the type specimen of *D. Sherwoodi.*

The new tooth is, however, quite distinct specifically from that, viz, it is much smaller, being only half an inch long, and has *three strong and two faintly defined, widely divergent, curved, obscurely tuberculated* ridges on the crown surface.

It is apparently undescribed, and I would propose for it the name of *Dipterus (Ctenodus) radiatus*, as expressing one of its most striking characters, the great divergence of the ridges as they leave their common starting-point in the center of the interior edge of the crown. A more detailed description can only be given when other specimens shall be obtained.

Gyracanthus Sherwoodi, n. sp.

Plate XVIII, Figs. 4–4b.

Spines four to six inches in length by half an inch in width, unsymmetrical, obliquely rounded or spatulate at the base, gently curved and acute at summit, much compressed laterally; central cavity reaching nearly to point, opening posteriorly only near the base; sides bearing numerous prominent, oblique, acute, beaded, parallel ridges.

This is a well-marked species, distinguished from all others known by its small size, compressed form, and highly ornamented surface. It most resembles *Gyracanthus Alleni*, N., of the Ohio Waverly, but is smaller and much more compressed. The only specimens known are ten spines in a bowlder seven by nine inches in dimensions found by Mr. Hess Cooper on Lamb's Creek, near Mansfield, Tioga County, Pa. The color and texture of this rock and the teeth and scales of *Holoptychius* which it contains prove that it came from the Catskill group.

For the opportunity of examining and describing these spines I am indebted to Mr. Andrew Sherwood, of Mansfield, Pa., the discoverer of so many remains of fishes in the Catskill and Chemung rocks, and the author of the Geological Report of Tioga County, published by the Second Geological Survey of Pennsylvania. As a slight token of recognition of the important services he has rendered to geology I dedicate the species to him.

Section C.—Fishes of the Waverly Group.

The Waverly group was so named by the first geological corps of Ohio, from a locality in the southern part of the State, where it is well exposed, and early became famous for the excellence of the building stone it furnished. Later studies of the group have shown that it consists of a number of elements which are locally quite distinct, but are not of great geographical extent. Where best seen, as in northeastern Ohio, it is about 500 feet thick, and fills the interval between the Erie shale (Chemung) below and the Carboniferous conglomerate above. It consists of several strata, as follows:

	Average thickness.
1. Cuyahoga shale	230 feet.
2. Berea shale	20 do
3. Berea grit	60 do
4. Bedford shale	75 do
5. Cleveland shale	50 do

In Pennsylvania the Waverly is represented by the Umbral shales and Vespertine sandstones of Rogers. In Kentucky the Waverly rocks are the "Subcarboniferous sandstones and shales" of Dr. D. D. Owen, and they are also locally known as the Knob stones, because they compose a series of knobs or hills bordering the Ohio valley. Here they become more calcare-

ous, and contain large numbers of the fossils which are found in the Carboniferous limestone, especially in the Keokuk division. West of the Cincinnati axis the Waverly formation is thin and scarcely distinguishable. In Michigan it is the Marshall group of Winchell, and is thicker and coarser, showing that we are there nearer the source of supply of the materials composing it.

In Kentucky, Ohio, and Michigan the Waverly strata contain a considerable number of fishes, and although much remains to be done in collecting and describing the fish fauna of this group, it has already yielded the following list of genera and species:

ELASMOBRANCHS.

Ctenacanthus formosus, Newb., Cuyahoga shale, Ohio.
triangularis, Newb., Cuyahoga shale, Pennsylvania.
vetustus, Newb., Cleveland shale, Ohio.
compressus, Newb., Cleveland shale, Ohio.
Clarkii, Newb., Cleveland shale, Ohio.
furcicarinatus, Newb., Berea shale, Kentucky.
angustus, Newb., Berea grit, Ohio.
cylindricus, Newb., Knob stones, Kentucky.
Hoplonchus parvulus, Newb., Cleveland shale, Ohio.
Asteroptychius elegans, Newb., Berea grit, Michigan.
Gyracanthus Alleni, Newb., Cuyahoga shale, Ohio.
compressus, Newb., Cuyahoga shale, Ohio.
inornatus, Newb., Cuyahoga shale, Ohio.
Cladodus subulatus, Newb., Berea shale, Ohio.
Pattersoni, Newb., Berea shale, Ohio.
Romingeri, Newb., Berea grit, Michigan.
Hertzeri, Newb., Bedford shale, Ohio.
concinnus, Newb., Cleveland shale, Ohio.
parvulus, Newb., Cleveland shale, Ohio.
Kepleri, Newb., Cleveland shale, Ohio.
Terrelli, Newb., Cleveland shale, Ohio.
Fyleri, Newb., Cleveland shale, Ohio.
tumidus, Newb., Cleveland shale, Ohio.
Orodus elegantulus, Newb., Cleveland shale, Ohio.
variabilis, Newb., Berea shale, Kentucky.
ramosus, Ag., Berea grit, Michigan.
Phœbodus politus, Newb., Cleveland shale, Ohio.
Polyrhizodus modestus, Newb., Cleveland shale, Ohio.
Stethacanthus tumidus, Newb., Berea grit, Ohio.
Helodus coniculus, Newb., Cuyahoga shale, Pennsylvania.
Mazodus Kepleri, Newb., Berea shale, Ohio.
Platyodus lineatus, Newb., Knob stones, Kentucky.

GANOIDS.

Gonatodus Brainerdi, Thomas, sp., Berea grit, Ohio.
Ctenodus Wagneri, Newb., Cleveland shale, Ohio.
Actinophorus Clarkii, Newb., Cleveland shale, Ohio.

PLACODERMS.

Dinichthys Terrelli, Newb., Cleveland shale, Ohio.
Gouldii, Newb., Cleveland shale, Ohio.
minor, Newb., Cleveland shale, Ohio.
corrugatus, Newb., Cleveland shale, Ohio.
intermedius, Newb., Cleveland shale, Ohio.
curtus, Newb., Cleveland shale, Ohio.
Titanichthys Agassizii, Newb., Cleveland shale, Ohio.
Clarkii, Newb., Cleveland shale, Ohio.
Diplognathus mirabilis, Newb., Cleveland shale, Ohio.
Glyptaspis verrucosus, Newb., Cleveland shale, Ohio.
Mylostoma Terrelli, Newb., Cleveland shale, Ohio.
variabilis, Newb., Cleveland shale, Ohio.
Trachosteus Clarkii, Newb., Cleveland shale, Ohio.

A few facts of special interest in regard to the fishes of the Waverly deserve to be mentioned, viz: In the black shale at Vanceburgh, Ky., formerly worked for the artificial distillation of oil, a very interesting series of fish remains was obtained by Mr. Patterson, which are now in the State collection at Frankfort, Ky. Among these is the tail of a shark which must have been eight or ten feet long; the outline of the entire fish was traceable on the shale, but only this part was preserved. The tail is about a foot and a half long, and very heterocercal; the vertebral column has entirely disappeared, and its place is marked by a smooth stripe between the spinous apophyses, which are plainly discernible. The rays of the lower lobe of the tail, nearly as large as one's little finger, are thoroughly ossified. Associated with this impression, but not in immediate contact with it, were numerous spines of *Ctenacanthus* and teeth of *Orodus*, all of which probably belong together.

A similar case of the ossification of the caudal fin-rays has been found by Dr. William Clark, at Berea, Ohio. Here the spines of *Ctenacanthus Clarkii* were so closely associated with the ossified fin-rays as to make it almost certain that they belong to the same fish, and the fins are connected with jaws which carry the teeth, called *Cladodus Pattersoni.*

The geological level at Vanceburgh is essentially the same as at Berea, Ohio. Teeth of a small species of *Cladodus* (*C Pattersoni*) are very common at both places, and at Vanceburgh a jaw was found which carries a large number of these teeth in place. They form many rows from front to rear (ten or more) and are nearly all of the same size, but some smaller ones

occur at the angles of the mouth. This specimen is in the Geological Museum of Columbia College, New York.

In the Waverly, on Oil Creek, Pennsylvania, Mr. G. K. Gilbert, found slabs of sandstone covered with the spines of *Ctenacanthus triangularis*, N.; a dozen or more lying within an area of two square feet. As only two could have been worn by one fish, their accumulation in such numbers is not easy of explanation.

The Cleveland shale, through northern Ohio, is a black carbonaceous mass, twenty to sixty feet in thickness. It there rests upon the argillaceous Erie shale, which at Cleveland is several hundred feet in thickness, but which thins out toward the west; in Lorain and Huron Counties it is sometimes wanting, letting the Cleveland shale down near to or upon the Huron shale, from which it can scarcely be distinguished by its lithologic characters. Over a large area, however, it is very distinct, and it is the source of the petroleum and gas of Grafton and Liverpool. It has also become celebrated for its fossil fishes. It is relatively barren of fossils, but, as in many other Carboniferous bituminous shales, at most localities the rhomboidal scales of Palæoniscoid fishes can be detected; these are highly polished, plain or ornamented, and somewhat abundant, but the fishes which bore them have never been found entire, and remain undescribed.

At Bedford, Ohio, the surfaces of the layers of the shale are sometimes covered with Conodonts, of which thousands occur on a square foot. They exhibit considerable variety in structure and dimensions, but nothing whatever is found with them which can explain their origin. Whether they are the teeth of Cyclostomous fishes, shell-less mollusks, or Annelids, remains undecided, but I know of no other locality where they are anything like as abundant as here. They occur in millions, and possibly careful study would reveal their history. In this locality I also obtained small teeth of *Polyrhizodus* and *Orodus* (*P. modestus*, N., and *O. elegantulus*, N.).

At Cleveland, the Cleveland shale forms a part of the hills which border the Cuyahoga Valley at its mouth, and is the surface rock in the cemetery where President Garfield is buried. From this region Mr. Frank Wagner, of Cleveland, has obtained a large number of bones and plates of *Dinichthys Terrelli* and one splendid and as yet unique tooth of a species of *Ctenodus*,

perhaps the finest of the genus. It is described and figured in another part of this memoir, and is named *Ct. Wagneri*, after its discoverer.

In the valleys of Rocky, Black, and Vermilion Rivers, all of which enter Lake Erie west of Cleveland, the Waverly rocks are freely opened. Rocky River, draining the Conglomerate area of central Medina County with its upper branches, and having its mouth in the Erie shale, cuts through the entire Waverly formation. Fish remains have been revealed at many levels in this section, and some of special interest. At the top of the Waverly at Medina, Bagdad, and Royalton we find three species of *Gyracanthus*, the only ones yet met with in the United States (*C. Alleni*, *C. compressus*, and *C. inornatus.*[1])

These are the pectoral spines of sharks, and were often used for crawling over shallows and shores, as we know by their worn condition; the young ones being perfect and acute, the older ones, which should have been nearly two feet in length, reduced to mere stumps, with every intermediate grade. All the spines of *Gyracanthus* yet known have been found in the Lower Carboniferous rocks in Europe, Canada, and the United States. Sir J. W. Dawson[2] has described two species of *Gyracanthus* (*G. duplicatus* and *G. magnificus*), and refers them to the Coal Measures; but Rev. D. Honeyman informs me that *G. magnificus* was obtained from the Lower Carboniferous limestone of Cape Breton. As to the other species, *G. duplicatus*, it is doubtful whether this should be included in the genus *Gyracanthus*.

At Berea, the Berea shale, the Berea grit, and the calcareous bands of the Bedford shale have all furnished the remains of fishes in considerable numbers, viz: In the Berea shale occur the teeth of *Cladodus Pattersoni*, and the striated rhomboidal scales of *Palæoniscus* (*Gonatodus*) *Brainerdi*, and Dr. William Clark has here found in the dove-colored clay-shale just above the sandstone, several specimens of *Physonemus* (*Stethacanthus*) *tumidus*, to which the rays of the pectoral fins are still attached. On the surface of the sandstone he has obtained a large number of these spines, but here denuded of all appendages. From the want of symmetry which they exhibit I had been led to consider them as pectoral spines. The specimens in which the

[1] Recently another species has been found by Mr. Sherwood in the Catskill rocks of Tioga County, Pa. It is described in another part of this memoir.

[2] Acadian Geology, p. 210.

fin-rays are in place also show a bulbous expansion of the proximal extremity of the spine, which apparently signifies an articulation; a natural feature in a pectoral spine, but never present in those of the dorsal line. In the Berea grit itself, at Berea, Independence, and especially at Chagrin Falls, Ohio, have been found numerous specimens of *Palæoniscus Brainerdi*, which sometimes attain a length of fifteen or sixteen inches and not unfrequently are found entire.[1]

In the pyritous layer of the sandstone at Berea Dr. Clark has obtained numerous specimens of three species of *Ctenacanthus*[2] (*Ct. formosus*, *Ct. Clarkii*, N., and *Ct. angustus*, N.), of which descriptions will be found in another part of this memoir. It is somewhat remarkable that with these spines no teeth have as yet been discovered.

In the calcareous bands of the Bedford shale Mr. H. Hertzer discovered years ago a species of *Cladodus* (*C. Hertzeri*),[3] which has the peculiarity that the external denticles are smaller than the intermediate ones, and these in their turn smaller than the central ones. This is perhaps a character which has generic value, but as the specimen upon which the specific description was based remains unique, I have hesitated to erect a genus upon a foundation so narrow.

In the Cleveland shale farther down the river Drs. Clark and Gould have obtained some of the most interesting remains of fishes yet found in Ohio. These are the cranium, dorsomedian plate, suprascapulas, and mandibles of *Titanichthys Clarkii* (the largest known Placoderm), and the same bones and plates of a small species of *Dinichthys* (*D. Gouldii*), in which are preserved the eye-orbits, surrounded by circles of four sclerotic plates, both of which will be found described in another part of this memoir.

Mr. Jay Terrell also and earlier found a cranium with the suprascapulas, clavicles, mandibles, etc., of *Titanichthys Agassizii* in the Cleveland shale on the banks of Black River.

[1] Dr. R. H. Traquair, of Edinburgh, has separated from the genus *Palæoniscus* certain species which have relatively small dorsal fins, set behind the middle of the back, with striated scales and teeth bent at an angle, under the name of *Gonatodus*. It is probable that *Palæoniscus Brainerdi* should be included in this category, but I have not yet seen any specimens in which the teeth were sufficiently well preserved to show whether they have the peculiar character which Dr. Traquair has made diagnostic of his genus.

[2] Described in Palæontology of Ohio, vol. 1, p. 328, pl. 36, fig. 2; vol. 2, p. 53, pl. 59, fig. 1.

[3] Palæontology of Ohio, vol. 2, p. 46, pl. 58, fig. 5.

Before closing this notice of the fishes of the Waverly in Ohio, I should refer to the discovery by Mr. M. C. Read, at Warren, Ohio, of a splendid dorsal spine (*Ctenacanthus formosus*[1]); also to a true fish-bed, filled with bones and teeth, generally fragments, discovered by Mr. McGuire at Youngstown. There is no doubt that the Waverly formation will prove to be rich in fossil fishes at various localities, and many new things are yet to be found in it. The great success which has attended the search of Messrs. Terrell, Clark, Gould, Hertzer, and Wagner in northern Ohio is an evidence of their energy and sagacity, rather than of any local richness of the deposit. It is altogether probable also that the Waverly of southern Ohio, Kentucky, western Pennsylvania, and Michigan offers fields which will as well reward thorough cultivation.

Dr. C. Rominger has kindly sent to me a collection of fish remains obtained in the Waverly rocks at Grindstone City, Mich., in which, with many imperfectly preserved specimens, are several spines and teeth of new species of sharks; and, what is of special interest, a splendid tooth of *Orodus ramosus*, Ag., one of the most characteristic fossils of the Carboniferous limestone of Armagh, Ireland.

SECTION D.—FISHES OF THE CLEVELAND SHALE.

The Cleveland shale, though a formation which never exceeds one hundred feet in thickness—generally less than one-half that—and occupying a limited area in northeastern Ohio, has proved to be the most interesting of all the fish-bearing strata in North American geology. It therefore deserves a few more words than are devoted to the description of the associated rocks. As already stated, it is represented in my reports on the geology of Ohio as a part of the Waverly series and of Carboniferous age. It is found outcropping in the hills which border the valley of the Cuyahoga, and good exposures of it are seen within the limits of the city of Cleveland. It is there fifty feet in thickness, a homogeneous mass of bituminous shale, and was one of the first strata distinctly identified when, at the organization of the Geological Survey of Ohio in 1869, the work of making out the geological structure of the State began. In all this region the rocks have

[1] Palæontology of Ohio, vol. 2, pl. 59, fig. 1.

a general though gentle dip toward the east, rising westward to the great arch of the Cincinnati axis. From Cleveland to Berea this rise is quite conspicuous, and in the early days of our geological explorations it was supposed to continue toward the west. Later, however, it was found that a broad arch was formed in the vicinity of Berea, and thence westward the Waverly series dipped rapidly down to the valleys of Black River and the Vermilion. This dip misled us, and the thinning of the Erie shale, bringing the Cleveland down near to the Huron, caused these two to be confounded, and led to the supposition that the fish-bearing black shales which form the lake shore in Lorain County were the upper part of the Huron; hence all the great Placoderms discovered by Mr. Terrell were at first referred to that formation. This matter was, however, cleared up by an excursion made by the writer westward from Cleveland in 1886, and it is now definitely established that all the outcrops of black shale in Cuyahoga and Lorain Counties belong to the Cleveland shale, and that none of the fossil fishes described from northern Ohio should be credited to the Huron.

From the Cleveland shale we have now obtained the remains of more than twenty species of fossil fishes, some of which in magnitude and interest surpass any others known. This has rendered the determination of its precise geological age a matter of special importance. In the reports of the Geological Survey of Ohio it was made a part of the Waverly series chiefly on the testimony of Mr. Andrew Sherwood, one of my assistants, who brought to me fragments of an earthy limestone which he claimed to have found in the valley of Tinker's Creek, near Bedford, Ohio, "*beneath the Cleveland shale.*" These specimens contained numerous Waverly fossils, among which *Syringothyris typus* was conspicuous. Subsequently, when a question was raised in regard to the accuracy of these observations, efforts made to rediscover the stratum of limestone reported by Mr. Sherwood were without success, and we are compelled to depend for the time being upon other evidence as to the age of the deposit.

As a general rule the Cleveland shale is very barren of fossils, many of its exposures having yielded nothing but the imprints of sea-weeds. Aside from the great fishes which are its characteristic fossils, and which, being all new species, do not decide this question, we have not a great array

of evidence. In the excellent exposures at Bedford, Ohio, except millions of Conodonts, having no geological significance, the only fossils found are the spines and teeth of three species of Elasmobranchs, *Hoplonchus*, *Orodus*, and *Polyrhizodus*. These three genera are characteristic of the Carboniferous system, and have never been found in the Devonian; but they will hardly be accepted as decisive, being specifically new. To solve this problem, Mr. M. C. Read and Prof. H. P. Cushing have within the last year made diligent search throughout northeastern Ohio for molluscous fossils in the Cleveland shale. Their efforts have been reasonably successful, as they have found large numbers of four species of Brachiopods, three of *Lingula* and one of *Discina*. In order to make the specific determination of these shells as certain as possible, they were submitted, without information as to their origin, to Prof. R. P. Whitfield, whose accuracy and palæontological knowledge are proverbial. He reports them to be *Lingula Cuyahoga*, Hall; *L. melie*, Hall; and *Discina Newberryi*, Hall; all well-known species of the Cuyahoga shale (Upper Waverly). The fourth species, not identified by Professor Whitfield, is a pointed *Lingula*, apparently undescribed, but found in the Bedford shale, which overlies the Cleveland, and is full of Waverly fossils.

The evidence, then, that the Cleveland shale is the basal member of the Waverly and a part of the Carboniferous system, as stated in the Ohio reports, though not overwhelming, may be considered as satisfactory.

Prof. Edward Orton, the present State geologist of Ohio, has in several of his recently published papers united the Cleveland, Erie, and Huron shales, and called them collectively the Ohio shale. This seems to me unwarranted, as these strata are essentially distinct in their fossils, and the upper and lower members of the trinity are separated on the eastern border of the State by an interval of at least one thousand feet. It is true that in western New York and Pennsylvania the rocks which represent the Huron and Erie shales of Ohio, viz, the Genesee shale, the Cashauqua shale, the Gardeau shale, the Portage sandstones, and the Chemung group are sufficiently distinct to be separately recognized and to receive different names. But in passing westward into Ohio they are found to thin and blend until they ultimately form two distinct strata; the upper—as we know by the

fossils—the equivalent of the Portage sandstone and the Chemung group (the Erie shale); the lower, which contains fossils of the Genesee and Portage shale, by the loss of the argillaceous members has become in central Ohio a nearly homogeneous bituminous shale three hundred to four hun-hundred feet in thickness (the Huron shale). At the mouth of Rocky River, at Cleveland and eastward to Erie, the lake shore is composed of gray shale, with bands of flaggy, often micaceous, sandstone and lenticular concretions of iron ore. This was named the Erie shale, as throughout the interval mentioned it has a distinct entity, and is not the equivalent of any one stratum or formation in New York. At Painesville the Erie shale, by the boring made at General Casement's house, was proved to have a thickness of seven hundred feet, and there to rest upon a black shale, from which it was sharply separated. From two hundred to three hundred feet of the upper portion of the Erie shale are here wanting, having been removed by erosion; but this portion may be seen by following up the valley of Chagrin River. Hence we have evidence that there the Erie shale is not far from one thousand feet in thickness and is essentially alike throughout; that is, is composed of soft dove-colored clay shale, with flags of sandstone.

Above the Erie shale we find in that vicinity, at the base of Little Mountain, the edge of the Cleveland shale; which, having a thickness of fifty feet at Cleveland, thins towards the east and apparently runs out before reaching the Pennsylvania line. All the fossils yet obtained from it are identical with those found in the Waverly beds above. Toward the west the Erie shale thins rapidly, and in Huron County is in one locality not more than ten feet in thickness. So far as known none of the fossils of the Huron occur in the Erie or Cleveland shales. Hence, to unite these three distinct formations is, in my judgment, to misrepresent the geologic record.

Prof. L. E. Hicks announces[1] the discovery of the Cleveland shale in Delaware County, Ohio, but I think he has found there the Berea shale, which lies immediately above the Berea grit. This latter shale is persistent southward, and is apparently the black shale, so rich in fish remains at Vanceburgh, Kentucky. I suspect the Cleveland shale does not pass south of the line of the Western Reserve.

[1] Am. Jour. Sci., 3d series, vol. 16, 1878, p. 70.

The following is a list of the fishes found in the Cleveland shale up to the present time:

1. *Titanichthys Agassizii*, Newb.
2. *Clarkii*, Newb.
3. *Dinichthys Terrelli*, Newb.
4. *intermedius*, Newb.
5. *minor*, Newb.
6. *Gouldii*, Newb.
7. *corrugatus*, Newb.
8. *curtus*, Newb.
9. *Glyptaspis verrucosus*, Newb.
10. *Diplognathus mirabilis*, Newb.
11. *Mylostoma Terrelli*, Newb.
12. *variabilis*, Newb.
13. *Trachosteus Clarkii*, Newb.
14. *Ctenacanthus vetustus*, Newb.
15. *Ctenacanthus Clarkii*, Newb.
16. *compressus*, Newb.
17. *Hoplonchus parvulus*, Newb.
18. *Orodus elegantulus*, Newb.
19. *Polyrhizodus modestus*, Newb.
20. *Cladodus concinnus*, Newb.
21. *Kepleri*, Newb.
22. *parvulus*, Newb.
23. *Fyleri*, Newb.
24. *Terrelli*, Newb.
25. *tumidus*, Newb.
26. *Ctenodus Wagneri*, Newb.
27. *Phœbodus politus*, Newb.
28. *Actinophorus Clarkii*, Newb.

Order PLACODERMI.

Genus TITANICHTHYS, Newb.

In 1883 Mr. Jay Terrell, of Sheffield, Lorain County, Ohio, found in the Cleveland shale, which had yielded to him so many bones of *Dinichthys*, the cranium and some body plates of a Placoderm fish of still more gigantic size. While evidently belonging to the family of Dinichthidæ it was generically distinct, and I gave it the name of *Titanichthys*.

As in *Dinichthys*, the head is triangular in outline, but the largest cranium of the largest known species of that genus, *D. Terrelli*, measures but three feet across the occiput, while the cranium of *Titanichthys* has a breadth of four feet or more.

The cranial surface, as in *Dinichthys*, is granulated or nearly smooth, and is ornamented with a series of incised lines or grooves ("Schleim Canäle"), which form a distinct and somewhat graceful pattern.

The dorsomedian shield is rounded in outline, about two feet in diameter, much thinner than that of *Dinichthys*, and with a long and relatively slender process, which reaches backward and downward apparently to gain the support of the neural spines.

The supra-scapulas are, as in *Dinichthys*, quadrangular or trapezoidal, lighter than those of *Dinichthys*, but broader; their longest diameter being from eighteen to twenty inches. They articulate with the cranium by a

strong and ingeniously devised joint. In *Dinichthys* a thimble-like process projects from the anterior border of the supra-scapula and plays in a conical cavity in the angle of the cranium. To prevent this conical condyle from getting wedged by sinking too deeply into the cavity, a guard projects from the under side of the angle of the head, upon which the supra-scapula rests. In *Titanichthys* the margin of the angle of the cranium is doubled, so as to form a deep groove, which is partially inclosed; that is, its margins approach each other. Into this groove a horizontal condyle, which is thinner behind than before, projecting from the anterior margin of the supra-scapula, may be slipped from the side. When thus inserted it cannot be directly withdrawn, but apparently had both a lateral and vertical motion.

Aside from the parts just mentioned, the clavicles, corocoids (?), sub-orbital plates, the mandibles, and a ventral plate are all that have been discovered of the two known species of the genus. We are, therefore, without the means of making minute comparisons, part by part, with the much better known dermal skeleton of *Dinichthys*. We have data enough, however, to determine that these gigantic bones represent a relative of *Dinichthys*, and yet one widely different. The area of corresponding parts is greater in *Titanichthys* than in *Dinichthys*, but all the superficial bones are much lighter. A strong frame-work was, however, required for the locomotive apparatus of so large a fish, and some of the bones of the shoulder girdle are remarkably massive and strong. The corocoid (?), for example, is nearly two feet in length, and one end is a massive, subcylindrical bone nearly as large as one's arm. The clavicles are more than two feet in length, but were composed of a relatively thin shell of bone, which was once lined and re-enforced with cartilage. The under jaws of *Titanichthys* are strikingly unlike those of *Dinichthys*. In one species, *T. Clarkii*, they have the same general form; that is, the posterior end is a spatulate oar-blade, the anterior more massive, turned up like a sled-runner; while in *T. Agassizii* the entire mandible, though nearly three feet long, is a slender rod. The jaws are, however, alike in this, that instead of having cutting edges or rows of denticles along the upper margin the anterior portion is deeply furrowed, evidently to receive some kind of dental apparatus which

has disappeared. This may have consisted of one or several bony wedges, or what is more likely, was a coating of horn, as in the turtles. Similar rods to the mandibles of *Titanichthys Agassizii* have been found beneath the head of Hugh Miller's *Asterolepis* (*Homostius*, Pander), a Placoderm closely allied to *Dinichthys*. These rods would be useless as organs of prehension or mastication, and the thought suggested itself to me, on seeing a fine series of heads in the hands of Dr. Traquair at Edinburgh, that they must have been sheathed in horn. The jaws of *Titanichthys* nowhere show the condensed tissue and acute worn edges of the mandibles of *Dinichthys*, and it is evident that such a bony dentition for cutting or piercing did not exist in the former genus. The texture of the bone where the teeth or cutting edges should be is porous, and shows no evidence of wear or use; hence it seems inevitable that it must have been sheathed with some denser material, that encountered the wear and violence to which dental organs are exposed.

Nothing corresponding to the plastron of *Dinichthys* and *Coccosteus*, composed of five distinct plates, has been found associated with the other bones of *Titanichthys*, but instead a single large triangular plate, which may have been its representative; at least its symmetry indicates that it was placed on the median line, and, since the back was covered with a dorsomedian plate, we are compelled to locate it on the under side of the body.

The affinities of *Dinichthys* and *Coccosteus* have been referred to in my description of *Dinichthys* in the Palæontology of Ohio, and it is certain that *Titanichthys*, *Asterolepis* (*Homostius* of Pander), *Heterostius*, and *Coccosteus* form a natural and closely assimilated group. The jaws of *Coccosteus* are imperfectly shown by Agassiz and Pander, and there was perhaps some variation of form in the different species; those they describe being narrow, flattened rods two or three inches long, bearing denticles on the upper margin near the anterior extremity. But I found in the British Museum a number of jaws of *Coccosteus* discovered since Hugh Miller, Agassiz, and Pander wrote about these fishes, in which the form is essentially that of *Dinichthys*, viz: the anterior extremity is turned up and forms a prominent denticle, and the whole organ is only a miniature copy of the mandible of *Dinichthys Hertzeri*. The difference in size is, however, very striking; one being three inches long, the other two feet.

TITANICHTHYS AGASSIZII, Newb.

Plate I, Figs. 1, 2; Plate II, Figs. 1, 2; Plate IV, Fig. 4.

Cranium about four feet broad at the occiput, triangular in outline, three feet or more in length, the nasal portion being imperfect in all the specimens known. The surface of the cranium is smooth or somewhat granulated, and is marked by incised lines, as is the cranium of *Dinichthys;* but these lines form a different pattern. The supra-scapulas of Owen—which should, perhaps, be regarded as supra-clavicles—are rhomboidal or trapezoidal in form and are about fifteen inches in the longest diameter. The clavicles are two feet in length by eight inches broad in the middle, strongly turned forward and narrowed at the lower end. The mandibles are from two and a half to three feet in length, subcylindrical or subtriangular rods of bone, roughly rounded or pointed behind and gently curved upward at the anterior extremity, where the upper surface is excavated by a deep groove, which is broader and more shallow anteriorly, giving to the extremity of the jaw the form of a gouge.

The suborbital bones are triangular in outline, sixteen inches or more in length, the anterior end pointed, the posterior rounded, and the upper margin excavated in a broad sinus around the eye. The surface is marked by two intersecting curved lines similar to those on the corresponding bone of *Dinichthys.*

The figures given on Pl. I are inside and outside views of the cranium drawn from photographs, and are about one-ninth the natural size linear.

The type specimen is now in possession of the Museum of Comparative Zoology at Cambridge, Mass., to which it was given by Prof. Alexander Agassiz.

TITANICHTHYS CLARKII, Newb.

Plate II, Figs. 3, 4; Plate III, Figs. 1-4.

Cranium triangular in outline, four feet four inches in breadth across the occiput, surface smooth or granular, marked by incised lines, which form a pattern indistinctly shown in the specimens yet obtained; supra-scapulas subrhomboidal in outline, twenty inches in width by thirteen inches in antero-posterior diameter; clavicles twenty-two inches long by eight inches

wide without the curved point; corocoid (?) twenty-two inches long, for one half its length a solid subcylindrical bone three inches in diameter, the other half fan-shaped and thinner. The mandibles are nearly three feet in length, the posterior end smooth, thin, spatulate, and curved downward, the anterior end gently curved upward, narrowed to an obtuse, gouge-like point and excavated in a deep furrow, of which the external margin is the higher and thinner; on the inside the margin is thicker and rounded.

Portions of the mandibles of this species were found some years since by Mr. Jay Terrell in the Cleveland shale on French Creek, in Lorain County, Ohio, but their nature was not recognized until explained by the discovery of two crania, with mandibles and many other bones, by Dr. William Clark in the Cleveland shale on the banks of Rocky River, near his place of residence, Berea, Ohio.

With commendable enthusiasm and industry Dr. Clark has followed up his first discovery by others, until he has now gathered a magnificent and unique collection of the remains of the great fish which has been named in his honor.

Among the mandibles of *T. Clarkii* found at Berea and on French Creek, Lorain County, Ohio, are some noticeable differences. Those obtained in the valley of Rocky River by Dr. Clark are represented somewhat restored in Plate II, Figs. 3, 4. They are nearly three feet in length, the posterior spatulate end about six inches wide and about three-quarters of an inch thick in the middle. A nearly complete mandible obtained by Mr. Terrell in Lorain County is about two and one-half feet long and much lighter, the posterior end being very thin. Another mandible from French Creek, of which the posterior half is complete, the anterior portion imperfect, is very much heavier. Compared with the other from the same locality mentioned above, and which has nearly the same linear dimensions, this is fully twice as thick and strong. These differences may be individual, sexual, or specific; the accumulation of more material will doubtless decide which, but meantime I have thought it best to notice them.

In comparing the bones of the two species of *Titanichthys* here described the differences in the mandibles will strike the most casual observer, and will perhaps suggest the question whether the two forms are generically

identical. But it will be noticed that the plan of structure is essentially the same in both forms; that is, they are weak as compared with the corresponding bones in *Dinichthys*, are alike in wanting teeth or cutting edges and in possessing a deep furrow on the upper side of the anterior end. We lack materials for making satisfactory comparisons with all the other portions of the bony structure, but it may be said that the crania are very much alike and the peculiar articulation with the supra-scapular plates are the same in both. These latter plates are also generally similar in both species, and the same may probably be said of the clavicles, though the material in hand is too imperfect for accurate comparison.

The dorsomedian plate is present in one of the specimens *T. Clarkii*, also a large plate represented by Pl. III, Fig. 1, which must have served for the protection of the under side of the body or head. Nothing corresponding to either of these two last-mentioned plates has been found in connection with the remains of *T. Agassizii*, but the missing parts will doubtless be discovered in the future. The suborbital plates of the two species represented on Pl. III, Fig. 2, and Pl. IV, Fig. 4, are very similar though distinct, and both are very much like the corresponding plates in *Dinichthys* and *Coccosteus*. From these facts it will be seen that the resemblances outweigh the differences, and that the probabilities are decidedly in favor of generic identity.

By the purchase of Dr. Clark's collection Columbia College has come into possession of all the specimens of *Titanichthys Clarkii* known, and they are now in the Museum of the School of Mines.

On the Structure and Relations of Dinichthys.

Since my papers on *Dinichthys* were published in the Palæontology of Ohio in 1875, a large amount of material has been collected, chiefly by Mr. Jay Terrell, of Oberlin, Ohio, which throws considerable additional light on the structure of the great Placoderm that bears the name of its discoverer, *D. Terrelli*. Also a number of new species have been found, some of which present most interesting peculiarities. *D. Gouldii*, for example, had enormous eyes and the eyeball was surrounded by a series of sclerotic plates similar to those of *Ichthyosaurus*. *D. intermedius* is another peculiar species, in which the denticles of the mandibles and maxillaries so conspicu-

ous in *D. Hertzeri*, of the Huron shale—the first species found—are represented by a few compressed teeth at the posterior ends of the cutting edges, which in this, as in all the later species, constitute the effective element in the dentition. These and other new species are described in this memoir, and therefore no further reference to them is needed here. I have also referred elsewhere to the discovery of the bony eye-capsules of *D. Terrelli*, as well as to the pair of plates which apparently protected the arched space between the mandibles (Pl. VI, Figs. 1, 1[a]).

The opening of a new locality rich in fossil fishes in the valley of the Cuyahoga and the suburbs of Cleveland has resulted in the discovery of material which has afforded valuable information in regard to the structure of *Dinichthys*, and has compelled the correction of some errors in my former descriptions. Among the fossils collected at this point by Dr. William Clark are several heads of *Dinichthys intermedius*, which show the structure with more completeness than any specimens before obtained. In most of the crania of *Dinichthys* obtained in Lorain County by Mr. Terrell the plates composing the cranium are so firmly united that their number, forms, and relations could hardly be made out. Those found in the new locality give us views of both the interior and exterior surfaces, where we can trace all the component parts. Some of these specimens are represented on Pls. LI and LII, and the points of structure now reported are there more or less distinctly visible. The most important contribution made by these specimens to our knowledge of the head of *Dinichthys* is shown in the outside view of the entire cranium of *D. intermedius*, Pl. LI; where the suborbital plates, here in position, are seen to be the bones which we have heretofore considered as the posterior lateral plates of the plastron. Inside and outside views of one of those bones are given on Pl. XLVII, Figs. 1, 1[a]. This species, which is much smaller than *D. Terrelli*, has the suborbital plates relatively very short. The position of the pair disinterred in the find made by Mr. Terrell, which furnished the originals of the life-size figures on the charts that accompany volume 2 of the Palæontology of Ohio, was such, that they were naturally referred to the plastron and were grouped with the central sternum-like plate and the two anterior lateral plates, which certainly belonged to the ventral armor. The later discoveries render it probable

that they should be referred to the sides of the head, and that their supposed places were really occupied by oblong or elliptical thinner plates which were partly covered with integument, and which have none of the incised lines that characterize all of the cranial plates.

In *D. Terrelli* the suborbital plates are sometimes eighteen inches in length and eight inches wide, oblong in outline, rounded behind, and without any evidence of contact with other plates. Hence it is not strange that they were considered the homologues of the "post-ventro-lateral" plates of *Coccosteus*. In *D. intermedius*, however, they are much shorter, and closely resemble in form and markings the suborbital bones of *Coccosteus*. They show, too, the incised lines which are wanting on the other bones of the plastron and are traceable on all the cranial plates. It is a singular fact that the pattern formed by these lines is the same in general plan in *Dinichthys* and *Coccosteus*, and is practically alike on the suborbital bones of *Dinichthys*, *Coccosteus*, and *Titanichthys*. Hence the position of these suborbital plates in the cranium now figured would seem to be normal, and we must replace them by others in the posterior part of the plastron. That other plates did occupy this position is proved by the rhomboidal expansion of the posterior end of the sternal plate, which by its beveled margins shows that it was overlapped by other plates on all sides. Since the bones of the plastron are always separated, we can only be guided in its reconstruction by finding places for all the cranial and dorsal plates, so as to complete the defenses of the upper side of the body, and then distribute the plates which covered the under surface according as they adapt themselves to those of which the places are known. The plates of the under side of the body were relatively thin, devoid of surface ornamentation, and were probably to a more or less degree covered with an integument. Of these, a pair which when united formed by their outlines a Gothic arch, I have supposed to be jugular plates, which filled the space between the mandibles. One of these is represented by outside and inside views, half size, on Pl. VI, Figs. 1, 1[a]. They are each semi-elliptical in outline, sixteen inches in length by seven and a half wide; the anterior ends are pointed; the outer margin is symmetrically arched; the inner margin nearly straight; the posterior ends are obliquely truncated and overlapped by the anterior extremity of a second pair of

plates. The first pair are smooth on the outer surface, about half an inch in thickness, the under side nearly smooth but somewhat radiately marked, as most of the plates of Placoderms are. Along their inner margins they overlap, so that the points are brought near together. By a singular and ingenious device they are prevented from slipping on each other by a deep notch in the edge of the upper plate, which surrounds and is filled by a corresponding conical ridge rising from the surface of the under plate; by this key they were firmly locked together. The posterior pair of jugulars—or as they should perhaps be called, hyoid plates—are long-triangular in outline, smaller than the anterior pair, but much thicker. Their anterior angles overlap and are sunk into the obliquely truncated ends of the jugulars. The outside and posterior ends of the hyoid plates are irregular and thin, and show that they were overlapped by other plates.

I have been led to conclude that the four plates just described covered the under portion of the head, because they were plainly on the median line, and when in apposition formed a shield, which had the proper outline, and would nicely fill the otherwise defenseless area between the mandibles and anterior to the plastron. It is evident that while so flat and so firmly locked together they would not be adapted to the protection of the posterior part of the body behind the plastron or the dorsomedian plate, the after part of the body requiring more flexibility than they would permit.

No figure is given of the plates which are supposed to have formed the posterior half of the plastron, because no perfect ones have been found, but I have numerous fragments of relatively large plates which must have been oblong in form and had the moderate and uniform thickness and plainness of surface which characterize the plates that defended the under side of the body. As they are apparently assignable to no other place in the armor of *Dinichthys* I provisionally locate them here.

Dr. Traquair, in his important paper published in the Geological Magazine of January, 1889, calls the suborbital bones of *Coccosteus* the maxillaries, and that would seem to be the most natural reading of the anatomical structure. But in *Dinichthys Terrelli* the dental armature of the upper jaw consists of a cleaver-like plate, of which the lower cutting edge played on the upper margin of the mandible like the blades of shears; a

very peculiar and effective style of dentition. This plate I have called the maxillary, though distinctly stating that it was not proved to be the homologue of that organ in other fishes or the higher vertebrates. In *D. Hertzeri*, of the Huron shale, the first described species of the genus, the "maxillaries," like the margins of the mandibles, are set with acute denticles; and in *D. intermedius*, now described, we see a connecting link between the two forms, the posterior margins of the cutting edges of the maxillaries and mandibles being set with compressed and scarcely functional denticles. The relations which the plates I have called maxillaries sustain to the "suborbital plates" of Owen, the "maxillaries" of Traquair, are intimate, since the former rest upon and are supported by the processes of the latter, which pass beneath and form the lower margins of the eye-orbits. Yet there was no bony union between them, and they are always found separated. Hence, if the suborbital bone is to be regarded as the true maxillary, these cutting plates must be considered as modified teeth; a view which I am inclined to adopt.

A similar question arises with reference to the homologies of the dental organs at the anterior extremity of the head. Professor Huxley calls the **T**-shaped plate which terminates the snout the pre-maxillary, while Dr. Traquair calls it the anterior ethmoid, and two little plates which are situated on either side of it in *Coccosteus*—plates not mentioned by Huxley—the pre-maxillaries. In *Dinichthys* there were apparently no plates corresponding to these so-called pre-maxillaries in *Coccosteus*, but instead are two great triangular dental organs, which meet on the median line and, diverging, interlock with the upturned points of the mandibles. These teeth I have provisionally called the pre-maxillaries, and if they were not such, the nasal plate must be considered as the pre-maxillary, and my "pre-maxillaries" as teeth, which are supported by the nasal bone in part and partly by the anterior edge of the preorbital plate. It will thus be seen that the dentition of *Dinichthys*, though remarkably effective, is very peculiar, and, so far as I know, without analogy with that of any other vertebrate than *Protopterus;* with this it has much in common, especially if we consider the two great anterior teeth as the homologues of the two so-called vomerine teeth of *Protopterus annectens.*

To proceed with our analysis of the cranial plates of *Dinichthys*, we find the nasal plate just referred to succeeded behind by an oblong or elliptical plate, which corresponds to the posterior ethmoidal of Traquair in the figure cited. By Huxley it is denominated the ethmoid. In all our specimens of *Dinichthys* we find in this plate what is not indicated or described by Pander or Traquair, a remarkable conical opening, which I have considered the pineal fontanelle, so marked a character in the crania of the buckler-headed Siluroids, *Arius*, *Phractocephalus*, etc. It is broad-trumpet-shaped, though oblique below, and penetrates the exterior wall of the cranium by a minute but persistent circular orifice.

The anterior angle of the head is formed by a quadrate plate, of which the outer margin is thin and excavated in an arch that forms the upper border of the eye-orbit. This is the plate called prefrontal by Huxley, preorbital by Traquair. It is followed behind by an oblong plate, very thick and massive, with a strong ridge below, bearing a robust columnar process, seen in both the views now given of the interior of the cranium of *Dinichthys*. The outer surface of this plate is marked in *Dinichthys* as in *Coccosteus* by an intersection of the incised lines which constitute the surface ornamentation so conspicuous in both.[1] By Dr. Traquair this is called the post-orbital plate. Behind this is a triangular plate or bone which terminates in a point and is the prominent lateral angle of the head; more pointed and posterior than in *Coccosteus*. Dr. Traquair calls its homologue in *Coccosteus* the marginal plate. I have represented a small specimen of this bone from the head of *D. Terrelli* on Pl. L, Fig. 1.

The middle portion of the posterior margin of the head in *Dinichthys* is formed by an extremely massive bone sometimes two inches in thickness, which has a triangular point at its center behind, as in *Coccosteus*. This plate is rarely found detached in *D. Terrelli*, but one such, seen from below is shown on pl. 59 of volume 2, Palæontology of Ohio. Near its center are the two pits, which are characteristic features of this bone in *Homosteus*, *Heterosteus*, and *Titanichthys*. By Owen and Huxley the plate occupying this position is called the supraoccipital; by Dr. Traquair, the medianoc-

[1] The "lateral line system" of Traquair; the "Haut (Schleim) Canäle" (mucus furrows) of von Koenen.

cipital. In *D. minor* it seems to have been easily separable from the other portions of the cranium, for we have many disarticulated specimens of it. One of these is figured on Pl. VIII, devoted to that species.

Between the supraoccipital and the marginal the space is occupied by an oblong and relatively thin plate, almost never separated from its associates except by fracture. This is the plate called by Dr. Traquair external-occipital, fully identified by its incised lines and by its articulation with the supra-scapula; it is called by Huxley the parietal-epiotic. In *Coccosteus* it is triangular in outline, but in *Dinichthys* it is narrowed behind by the angle of the head being brought so far backward. This is the plate with which the suprascapula articulates in the wonderful joint to which I have so frequently made reference. It is pierced at its inner posterior angle by a vertical, thimble-like socket, into which the condyle of the suprascapula fits in such a way that it cannot be withdrawn without being lifted vertically. Apparently to prevent the binding of this joint, a thumb-like guard is thrown out from the angle of the head and passes under the edge of the suprascapula.

The central portion of the head in *Dinichthys* is occupied by an irregular plate, which is probably divided by a suture down the middle, though never separating along this line. It is identifiable by its relations to the surrounding plates and by the lines of ornament (essentially the same in both genera) with the plate in the cranium of *Coccosteus* called frontal by Huxley and central by Traquair.

The defenses of the back of *Dinichthys* formed by the great dorsal plate and the supra-scapulas have been so fully described in the Report of the Geological Survey of Ohio, that little more remains to be said about them. The resemblance of the dorsal plate of *Coccosteus* to that carried on the back of some of the plated Siluroids has been remarked upon by Huxley, Owen, and Hugh Miller. The similarity is as marked in the dorsal of *Dinichthys.* Its position and functions are not only the same, but it is supported by a process extending from the posterior margin down to the neural spines, just as the dorsal plates of the Siluroids are; so that there can hardly be a doubt of its being their homologue and an inherited character; one of the many which connect the Siluroids and the Placoderms. The form of this

plate varies considerably in the different species; being quadrangular in *D. Terrelli* and *D. intermedius*, more rounded in *D. Gouldii* and *D. minor*.

The suprascapulas are oblong and closely resemble in all things but size those of *Coccosteus*. Their upper margins are overlapped by the dorsal plate, while the lower margin is covered by the bifurcated expansion of the clavicles. These latter have never before been figured, though good specimens have been in my possession for several years. One of a complete pair is represented, one-third natural size, by inside and outside views on Pl. XLVIII.

Internal bones belonging to the shoulder girdle have been found in many instances. These I have provisionally called coracoids, but I am by no means sure of their proper relations. They are sometimes a foot and a half in length, somewhat curved, subcylindrical at one end and in the middle, expanded and flattened at the other; are nearly as large as one's arm, and consist of dense bony tissue.

On Pl. VI is figured a triangular bone with which I have long been familiar, but I am not yet able to fix with certainty its position on the body. It is sometimes an inch in thickness at the center and the largest specimens are nearly a foot and a half in length. Only the central portion was exposed, the ends and curved margin being deeply marked by the impressions of overlying plates. A short furrow belonging to the lateral line system passes from what was apparently the upper side to about the center of the exposed portion and there vanishes. The straight or nearly straight edge is rounded, shows no indications of contact with other plates, and was evidently free. Two places have suggested themselves as possible for this plate: one behind and overlapped by the suborbital plate, in that case forming the continuation of the upper margin of the mouth; another and more probable place was in the angle between the lateral margin of the dorsal plate and the posterior margin of the suprascapula. From the condyle on the anterior margin of the latter plate a furrow runs obliquely backward to the posterior margin and would seem to have been continued on some adjacent plate. A similar triangular plate occupies this position in *Coccosteus*, and waiting the time when it shall be found in its normal place, we may provisionally fix it here.

The mandibles of *Dinichthys Terrelli* and *D. Hertzeri* have been already fully figured and described.[1] I now give good figures of the mandibles of *D. intermedius* and less satisfactory ones of more imperfect jaws of some of the smaller species.[2] They exhibit considerable diversity of form, and it is desirable that when more perfect specimens are found they shall be represented so as to show the range of variation in this part of the bony structure. In *D. Gouldii* the cutting edge was nearly straight, the bevel more obtuse than in the larger species; the posterior end was also much narrower, straighter, and thicker relatively than in any other known to me.

My remarks on the relations and structure of *Dinichthys* contained in the second volume of the Palæontology of Ohio were written before we had obtained a complete suite of the bones, and I was therefore unable to point out all of the features which it had in common with *Coccosteus*. Later discoveries strengthen the force of the comparison then made. The cranial plates, the suborbitals, the suprascapular and dorsal plates are as much alike as possible with the differences in the general form of the head, which is hexagonal in *Coccosteus* and triangular in *Dinichthys*. So the plastron is composed of homologous plates having practically the same number and similar forms, although in *Coccosteus* the sternal element consists of an anterior triangular plate and a rhomboidal central one, while in *Dinichthys* they are connected by a bony band.

It has been supposed that the dentition of *Coccosteus* and that of *Dinichthys* were radically different, but I have learned that they were very much alike. The mandibles of *Coccosteus* that have been figured are all imperfect, the anterior ends being crushed, distorted, or wanting; yet, as I have mentioned elsewhere, I recently found in the South Kensington Museum a mandible of *Coccosteus* which was a perfect miniature of that of *Dinichthys*, being spatulate posteriorly and having the anterior end turned up to form a conspicuous denticle. In regard to the dentition of the upper jaw in *Coccosteus* we are as yet not well informed, and therefore a satisfactory comparison can not be made.

The foramen which penetrates the center of the head of *Dinichthys*, passing through the middle of the ethmoid plate, has been referred to above.

[1] Paleontology of Ohio, vol. 1, p. 316, pl. 30; vol. 2, pp. 7, 8, chart V. [2] This Monograph, Pls. X, LXIII.

It is as distinctly marked in the head of *Titanichthys*, and its position is indicated in the figure of the cranium of *T. Agassizii* given on Pl. I and copied from a photograph. I have also represented the inside of the ethmoidal plate of *Dinichthys* with the funnel-shaped orifice penetrating it on Pl. LI, Fig. 3. It seems to be homologous with the aperture in the cranium of Reptiles, Amphibians, and the Siluroid fishes which has been called the pineal eye, and about which so much has recently been written. It has long seemed to me that the functions of this aperture, which is so very marked in the Siluroids, should be investigated by the microscopic study of the soft parts, and at my suggestion Mr. Bashford Dean, one of my students, has begun a research which it is to be hoped will clear up this question so far as the fishes are concerned.

A color of probability is given to the suggestion that this orifice was at one time an eye, by the fact that in *Pterichthys* and *Bothriolepis* a dumb-bell or double aperture on the top of the head formed almost certainly the organ of vision; no other eyes being known in these fishes and no other use for these apertures being conceivable. In the allied but very distinct *Cephalaspis* the eyes are separate but closely approximated, as though the ancestors of this group of fishes had been monoculous; *Pterichthys* and *Cephalaspis* representing different stages in a progressive separation of the sight organs. If this were true, however, *Dinichthys*, which was certainly as old as either, had progressed very much further along this line of development; since the eyes in this genus were as fully elaborated and specialized as in any living fishes.

It is certain that the perforation of the cranium in *Dinichthys* and its allies, as well as in the buckler-headed Siluroids, in which the brain-box is so strong and complete, served an important purpose, and it is to be hoped that the investigations of Mr. Dean will tell us what was its function.

The Fins of Dinichthys.

Plate VII, Figs. 1–1^b.

Ossified fin-rays have several times been found by Mr. Terrell associated with the bones and plates of *Dinichthys Terrelli*. Usually they are separated, but in some cases they have been found lying side by side in

the relative positions they occupied in the fin. One such group of fin rays is shown in Pl. VII, Fig. 1.

The individual rays are from two and a half to three and a half inches in length, quadrangular in section, half an inch broad by three-eighths thick. They are composed of a shell of dense bony tissue surrounding a cavity which, in uncrushed specimens, is now filled with pyrites, and was probably once occupied by cartilage. The articulations are not preserved, and they were apparently cartilaginous. These fin rays probably represent the first or basal row; the exterior subdivisions having disappeared, perhaps because they were cartilaginous, perhaps because they had been eaten away by some of the smaller fishes of the sea in which *Dinichthys* lived.

From the numbers of fin rays found together, a dozen or more, and these forming only part of the base of the fin, as well as from their strength, straightness, and symmetry, I am inclined to consider such groups as that now figured as belonging to the dorsal fin.

Remains of the pectoral fins of *Dinichthys* have been earnestly sought for, and it seems probable that they have finally been found. In the remains of *Coccosteus* studied by Hugh Miller, Agassiz, and Sir Philip Egerton no traces of pectoral fins were met with, though a dorsal fin is frequently traceable in their specimens. Recently Prof. A. von Koenen, of Göttingen, has discovered, in connection with some unusually well-preserved specimens of *Coccosteus*, what he considers as the "ruder organe," or pectoral fin spine. This is straight and staff-like, rounded at its anterior, pointed at its posterior extremity; on its outer face it is ornamented with the characteristic tubercles of *Coccosteus*, within rough or longitudinally striated, as though for the attachment of muscles, a fin membrane, or soft fin rays.[1]

The zoologic affinity between *Dinichthys* and *Coccosteus* is so intimate, that it was to be expected if *Coccosteus* had fin spines, something of the kind would be found with the remains of *Dinichthys*, and I am now able to report the probable discovery of these. Alongside the outer margin of the plates composing the ventral shield, detached, splint-like bones have several times been noticed, of which the position and use have till now been unsuspected.

[1] Beitrag zur Kenntniss der Placodermen, Abhandl. könig. Gesell. d. Wissen. zu Göttingen, vol. 30, 1883.

These, I am inclined to believe, are pectoral spines or bony supports of the pectoral fins, different in form from those of *Coccosteus*, but similar to them in function. These bones are generally ten or twelve inches in length, subtriangular in section, with one broad, flat, or gently arched surface, while on the other side is an obtuse central keel with sloping sides. The ends are irregularly sharpened as though buried in cartilage. A narrow zone of the broader surface is flattened and smooth and may have been exposed, while the margins, ends, and under side were plainly covered with integument of some kind.

Probably these bones formed the anterior margin of the pectoral fins, articulating with the shoulder girdle by a cartilaginous joint. Confirmation of this view is afforded by the fact that they are distinctly in pairs, and not more than one or two have been found with any group of *Dinichthys* bones. Outside and inside views of these bones are given on Pl. V.

THE EYES OF DINICHTHYS.

Plate VII, Figs. 2, 2[a].

Only one head of *Dinichthys* has been found in which the parts were substantially in their proper positions. This was obtained in 1867 by Mr. H. Hertzer from a calcareous concretion near the base of the Huron shale, at Delaware, Ohio. The entire head was present, but the occipital portion was considerably mutilated in removing the stone which enveloped it. The anterior extremity of the head showed a broad, flattened muzzle with the great premaxillary teeth in place; behind these the maxillaries, with their denticulate margins, and beneath all the two mandibles with their extremities turned up, forming triangular teeth, which interlocked with the premaxillaries. One suborbital bone was in its proper position, and in the deep sinus of its anterior and upper side the place of the eye could be determined, but nothing was left of it.

In subsequent years many heads of *Dinichthys Terrelli* in a better or worse state of preservation were discovered by Mr. Jay Terrell on the shore of Lake Erie. In some of these the cranium was nearly complete, but the associated plates, jaws, and teeth were either absent or scattered irregularly

about in the vicinity. None of these heads showed any traces of the eye orbits, and they remained unknown until 1885, when Drs. Gould and Clark, of Berea, Ohio, found in the valley of Rocky River the head of a small and new species of *Dinichthys (D. Gouldii,* N.*)*, of which the eye orbits were preserved. The length of the cranium was about a foot; the opening of the eye was elliptical in outline, an inch by an inch and a quarter in diameter, and was surrounded by a circle four inches in diameter, composed of four sclerotic plates. This showed that the eye of *Dinichthys Gouldii* was much like that of *Ichthyosaurus* and relatively as large.

In regard to the structure of the external eye in the other species of *Dinichthys* we have until recently had no information. It was deemed probable that their eyes were provided with sclerotic plates, but from the fact that they had not been found with the other portions of the head I had supposed that they were cartilaginous and had perished. Since the MS. for this monograph was sent to the printers a head of *Dinichthys curtus* has been found by Professor Kepler at Linndale, Ohio, which shows that the eyes of this species also were protected by bony sclerotic plates. They are described on another page.

Several years ago Mr. Terrell called my attention to some perforated bones which he found adhering to the inside of the skull of *Dinichthys Terrelli.* They were not always in the same position, but they were two in number, one on each side, and located well within and near the anterior extremity of the head. These bones were conical in form and elliptical in section, having a broad excavated cup at the larger end, a narrow and deeper one at the smaller, with an orifice a quarter of an inch in diameter connecting the two depressions. The shallower cup of the larger end was uniformly arched and had a kind of raphe on the bottom along the line of greatest diameter. From this radiated a series of dark bands, bundles of tubes or fibers, passing with great regularity and exactness to the lip or margin of the cup.

These singular bodies have been a great puzzle to me. I was at first disposed to consider them otoliths, but better-preserved specimens showed the hour-glass structure with the central perforation and the regularly radi-

ating bands of the larger cup, which were characters not exhibited by the ear stones of any fishes known to me. In these circumstances I was forced to regard them as part of the optical apparatus, and a study of the organs of sight in fishes of different groups h: s given me the conviction *that they are the optic capsules*, which held the lens and vitreous humor in the broader cup—of which the margin perhaps supported a circle of sclerotic plates, perhaps was a substitute for them—and that the central perforation was for the passage of the optic nerve. In most fishes of the present day the eye capsule consists of two hemispherical cartilaginous cups; but in many these are bony, and in some, as *Ceratodus*, *Xiphias*, etc., they are united to form ovoid or cup-shaped bony shells, which hold and support the lens and have an orifice for the passage of the optic nerve.

In many fishes the crystalline lens has a peculiar banded structure, and in some—as the cod—the bands radiate from and converge to opposite poles, like the meridians on a terrestrial globe, while in others—as salmons and sharks—they converge to a line or septum instead of a point at each pole. The figure formed by the intersection of the radial fibers and the septum is a very elegant one, and precisely that which is found in the bottom of the hemispherical or semi-elliptical cup of the broader end of the conical bones under consideration. In *Xiphias* and *Tetrapterus* the eye capsules are elliptical or sub-globular shells of bone, which inclose all the optical apparatus. Over the large orifice the cornea is stretched like a drum-head, while below is a smaller opening for the passage of the optic nerve. *These bony shells are marked at each end of the ellipse by radiating lines much like those in the organs which I have considered the eye capsules of Dinichthys*, and this structure affords additional evidence of homology.

Taking all these facts into account, I think we may assume with a good degree of confidence that in these turbinated bones found in the anterior portion of the head of *Dinichthys* we have the osseous capsules which supported the globes of the eye.

In Owen's Palæontology, second edition, page 144, it is said that Mr. David Page found in the tile-stone of Lanarkshire, Scotland, the base of the Devonian system, a *Cephalaspis* which, with a dorsal, pectoral, and a large heterocercal caudal fin, "*had well-marked eye capsules.*"

Dinichthys minor, Newb.

Plate VIII, Figs. 1–8.

Dinichthys minor, Newb.; Annals N. Y. Acad. Sci., vol. 1, 1879, p. 191.

The dorsal plate of this species is about eight inches long, of which little more than half is occupied by the dorsal shield, the remainder being made up by the long and slender neck, which forms the extension of the crest of the inferior side. The plate itself is shield-shaped, terminating anteriorly in an acute point, posteriorly in an obtuse one. The sides, irregularly rounded, run to a feather-edge, which was probably buried in the integument. The superior surface is marked by several obtuse, longitudinal striæ, and by a peculiar transverse, crape-like wrinkling. Near the anterior border are some corrugations which look like places of muscular or cutaneous attachment, and the whole aspect of the upper surface is more that of a buried than a superficial bone. The under surface is uniformly excavated and arched transversely on either side of the low and sharp central crest. This crest is prolonged into a narrow, neck-like process, which projects backward and downward from the posterior margin of the shield, and is excavated in a broad furrow along its upper surface.

The supra-occipital bone, which seems to have readily disarticulated, is two and one-fourth inches long by three inches wide, rounded behind, with a low point at the center of the margin; anterior portion wedge-shaped, truncated. The upper surface is marked by several broad shallow furrows, separated by low, obtuse, radiating ridges, the whole marked with the characteristic crape-like wrinkling. The under surface shows a backward slope with a prominent ridge, which forms the terminal point. Anterior to this slope is a semi-elliptical excavation bordered posteriorly by a relatively sharp ridge, the anterior margin of the slope mentioned above. In the bottom of this excavation are two shallow pits separated by a low ridge, as in the other species of *Dinichthys* and the allied genera. The anterior portion of the inferior surface slopes rapidly upward. The dentition is not certainly known, but an imperfect jaw found with the specimens described above and corresponding in size is some four inches in length, and consists of an exposed and a buried portion as in *D. Terrelli*. The posterior extremity is

thin and relatively short and broad; the anterior portion, composed of very dense tissue, is thick, polished without, and terminates above in a sharp cutting edge; the extremity is broken away.

The outside of this jaw is shown on Pl. VIII, Fig. 5. It will be seen that all the anterior portion is gone, and it is only interesting as showing the peculiar broad and short outline of the posterior extremity. Recently another small jaw has been found by Mr. Terrell, which is represented in Fig 6 of the same plate. This apparently belongs to the same species, though to a somewhat smaller individual. In this specimen the posterior extremity is wanting, but the anterior is nearly complete, and it therefore supplements the one before mentioned. In the figure given the inside of this jaw is shown; the second denticle is unfortunately broken away, but its position is plainly shown by the fracture and the ridge which runs up to it. These prove that it is situated at an unusual distance from the anterior point.

In Figs. 7, 8 are given views of a premaxillary of a small species of *Dinichthys* which is quite different from any other we have met with. In Fig. 8 it is seen in profile, and in Fig. 7 from above. It will be noticed that it is flatter and more obtuse than the corresponding organ in the other species of *Dinichthys*, and that it bears a row of tubercles along its anterior angle; a character which is also present in the very different premaxillary of *Dinichthys Hertzeri.*

DINICHTHYS GOULDII, n. sp.

Plate IX, Fig. 1; Plate X, Figs. 1, 2.

Fishes of relatively small size; cranium about twelve inches in length and breadth; dorsomedian plate circular or transversely elliptical in outline; external surface marked by concentric lines and roughened as though covered by integument; inferior crest and neck relatively thin and small; suprascapular bones trapezoidal in form, five inches wide by three inches long; mandibles seven to eight inches long, relatively narrow; posterior and buried portion spatulate, blunt pointed, narrow, and thick; cutting edge ong, nearly uniform throughout, bluntly beveled; premaxillaries triangular in outline, two inches broad above, one and a quarter inches in vertical

height, smooth, and relatively thin; suborbital bone six and a half inches long, broadly rounded behind, with a deep sinus above to receive the eye; it is relatively thin, and was apparently covered by integument; eye very large, orbit elliptical, one and a half by one and a quarter inches in diameter, surrounded by four thin, anchylosed, sclerotic plates, which are on the outside smooth or finely granulated, within radiately striate.

This species was discovered by Dr. D. T. Gould in 1886 in the valley of Rocky River, below Berea, Ohio. The head, dorsomedian and suprascapular plates, a suborbital bone, one premaxillary, and portions of two mandibles were found together, and with them two circles of sclerotic plates, one dislocated the other entire, by which the orbits were surrounded. These circles were formed of four pieces nearly equal in size; the aperture of the eye was elliptical, an inch and a half long; the ring of circumorbital plates was somewhat elliptical in outline and four inches in its longest diameter. In life the eye must have had somewhat the aspect of that of *Ichthyosaurus* and was relatively as large. Whether other species of *Dinichthys* had eyes of similar construction and equal size can not yet be said, but the form and size of the suborbital plates and the depth of the sinus which received the ocular apparatus indicate large eyes in all the genus, but relatively smaller than in the present species. To maintain the same proportions the eyes of *D. Terrelli* would need to be about a foot in diameter. It seems probable, too, that *D. Gouldii* was peculiar in having ossified plates around the eye orbit. If the larger species of the genus had possessed similar bony plates we ought long since to have become familiar with them, but none have been found; and we may hence infer that the external envelopes of the eye were cartilaginous. This species has been dedicated to Dr. D. T. Gould, the discoverer.

DINICHTHYS CORRUGATUS, n. sp.

Plate VII, Figs. 3, 3a.

Of this species we have only the anterior half of a mandible. This mandible was originally six inches long but all the flattened spatulate portion is wanting. That part which has been preserved is the thicker, denser, and more exposed anterior end. This is broken along the upper margin, so

that it is impossible to say whether it carried denticles or a cutting edge. The anterior extremity formed an acute and polished tooth, bearing a carina along its anterior border; below, the mandible is uniformly arched and terminates in a rather sharp edge; outside it is peculiarly corrugated and roughened. On the inside it shows the same rough bony surface, with a furrow parallel to the lower margin. The posterior extremity, where broken off, is quite narrow and thick, and it is evident that the fracture was just along the line between the exposed and covered portions. No evidence is given by an internal ridge of the presence of a second point on the upper margin, but a small denticle may have existed there where the margin is broken away. This mandible differs from all others known to me by its narrowness, the roughness of the surface, and the similarity and simplicity of the inner and outer surfaces.

Formation and locality: Cleveland shale; Black River, Lorain County, Ohio. Collected by Mr. Jay Terrell.

DINICHTHYS INTERMEDIUS, n. sp.

Plate X, Figs. 1, 2; Plate XLVII, Figs. 1–4[a]; Plates LI, LII.

Cranium fifteen inches in length and width; mandibles having the general forms of those of *D. Terrelli*, but smaller—fifteen or sixteen inches in length; posterior portion of cutting edge of dentary bone set with compressed, lancet-shaped denticles; maxillaries about four inches long by two inches wide, strongly arched vertically, and like the dental plates of the under jaw carrying denticles on the posterior margin; premaxillaries apparently similar to those of *D. Terrelli*, but much smaller; suborbital plates relatively short, the expanded portion being in some cases nearly square and about four inches long and broad; eyes about three inches in diameter. The dorsal shield and supra-scapulas are rounder in outline than those of *D. Terrelli* and, like the other parts mentioned, are about half as large. Of the plastron the anterior lateral plate is shorter and relatively broader than in the larger species, the posterior ventral plate oblong in outline, about as large as the anterior plate, but thinner.

Some years ago a mandible of *Dinichthys* of medium size was found by Mr. Jay Terrell in Lorain County, Ohio, which, with the general form and

proportions of that of the larger species, had this peculiarity, that the posterior end of the cutting edge carried denticles. At first sight these resemble those on the mandibles of *D. Hertzeri*, but when examined they are seen to be compressed and to be only strong serrations, which could have had little functional importance. This character seems to be an inheritance from the older species of the genus, *D. Hertzeri*, in which both the mandibles and maxillaries are set with conical pointed teeth, and thus it is a kind of connecting link between that form of dentition and the cutting edges of the mandibles and maxillaries of *D. Terrelli*, etc.

It is not true, however, that all the earlier species of *Dinichthys* had pointed teeth on the mandibles and maxillaries and all the later ones cutting edges, for Prof. J. M. Clarke has described in the Bulletin of the U. S. Geological Survey, No. 16, page 17, the mandibles and maxillaries of a species of *Dinichthys* which he calls *D. Newberryi*. They are about the size of those of *D. intermedius*, and have cutting edges precisely as in *D. Terrelli*. These specimens were found in the Hamilton shales of western New York, the geological equivalents of the Huron shale of Ohio. Hence *D. Hertzeri* and *D. Newberryi* were contemporaries, and the two styles of dentition were in use at the same time. The dentition of *D. intermedius* does not therefore represent a phase of progressive transition from one form to the other, characteristic of an intermediate period, but is rather a kind of hybrid between the two older forms.

After the discovery of the first mandible with the characters mentioned above a number of others were obtained, all of about the same size and having the compressed denticles at the back end of the cutting edge. I have therefore been led to accept the suggestion first made by Mr. Terrell, that these represent a distinct species, and I have given it a name indicative of the intermediate position it holds between the larger and smaller forms of *Dinichthys* found in the Cleveland shale and also in the denticulation of the mandibles between them and *D. Hertzeri* of the Huron shale. It should also be mentioned as confirmatory of this view that these smaller mandibles are as much worn by use as any of the larger ones; from which we may infer that they belonged to mature individuals. I may add that in the Cleveland shale at Brooklyn, Cuyahoga County, Ohio, while the remains

of this species are somewhat abundant, scarce any traces of *D. Terrelli* have been discovered.

Mr. Terrell has obtained from Lorain County, Ohio, several crania, dorsomedian and supra-scapular plates of intermediate and small sizes which may have belonged to the species under consideration. Among these is a pair of supra-scapulas about half the size of those of *D. Terrelli* and with much rounder outlines. The dorsal plates have little to distinguish them from those of *D. Terrelli* except their smaller size. Some of these bear marks of the teeth of the larger species; by which it is made evident that the smaller ones were often attacked by them, and in one specimen we have proof that such attacks sometimes proved fatal. The specimen referred to is a dorsal plate that, with the posterior process, must have been originally about fifteen inches in length, of which the wings are crushed quite together, as though by violence, and still bear deep pits and furrows, evidently made by the "mandibles" and "premaxillaries" of *D. Terrelli*, between which it was seized and crushed. In this specimen we have evidence that the gape of the mouth in *D. Terrelli* was wide enough to embrace a body a foot or more in diameter, and that the jaws were moved by muscles of such power as to deeply indent and even crush the armor of the smaller species of the genus.

Since the above notes were written Dr. William Clark has obtained from the Cleveland shale in the valley of the Cuyahoga a large number of bones and plates of *Dinichthys* which we may confidently refer to this species. Of these several are figured on Pls. XLVII, LI, and LII. They include crania of which nearly complete specimens are figured on Pls. LI and LII, the first the outside showing the suborbital plates in position; second the inside with the supra-scapulas attached to the skull. The suborbital bones, though relatively and absolutely much shorter, are apparently the homologues of the plates which I have figured and described in the Palæontology of Ohio as the posterior pair of the plastron. One of these, which I have with some doubt referred to *D. intermedius*, is represented in views of the outside and inside on Pl. XLVII, Figs. 1, 1[a]. These and many others are in the collection recently purchased of Dr. Clark, all of which are relatively longer than this. I was therefore at first inclined to regard

it as representing the species, to which I had given the name of *D. curtus*, but am rather inclined to the opinion that it is only a variety of *D. intermedius*.

As mentioned in the general discussion of the relations of the genus, this plate corresponds so closely in form and markings with the so-called suborbital of *Coccosteus* that they must be homologous, and Dr. R. H. Traquair, in his paper on the relations of *Homosteus* and *Coccosteus*, in the Geological Magazine for January, 1889, advances the view that they are really the maxillaries. Should that prove true, we shall be compelled to consider the dental plates with cutting edges (Pl. XLVII, Figs. 3, 4, 4[a]) as modified teeth.

On Pl. LI, Figs. 2, 3, I have given photographic views, half size, of the inside and outside of the anterior extremity of the cranium of *D. intermedius*. These show distinctly the nasal plate, behind this the ethmoid, and on the sides the preorbitals. In Fig. 3 is represented the under side of the ethmoid with the pineal fontanelle, with the minute foramen which pierces the skull. On the left side of Fig. 3 is seen the roof of the eye orbit, and part of its upper margin complete. The suborbital plates in this specimen should be brought forward so as to form with the preorbital and postorbital plates a nearly circular orbit, which was about three inches in diameter. This indicates a large eye, yet not as large as that of *D. Gouldii*, although that was a smaller species. No traces of sclerotic plates have yet been found in connection with the head bones of *D. intermedius*, though this is not proof that they did not exist. Attached as they were to the eye, a movable and perishable organ, they would be very likely to be scattered, and if thin and delicate, destroyed.

In this connection I would call attention, as I have elsewhere omitted to do, to the resemblance of the ring of sclerotic plates of *Acanthodes* to those of *Dinichthys* and *Coccosteus*. Dr. Ferd. Roemer has given a beautiful figure of the sclerotic plates of *Acanthodes* in the Zeitschrift der deutsch. geol. Gesellschaft, vol. 9 (1857), page 51, pl. 3, and he has shown that it consists of four pieces, as in *Dinichthys Gouldii* and *Trachosteus Clarkii*. In A. von Koenen's figures of the sclerotic ring of *Coccosteus*[1] it appears to be

[1] Beitrag zur Kenntniss der Placodermen, Abhandlungen der königlichen Gesellschaft der Wissenschaften zu Göttingen, vol. 30 (1883), pl. 4, figs. 1, 2.

entire, but that is perhaps due to the removal of the plates, which left an imperfect impression upon the internal cast.

DINICHTHYS CURTUS, n. sp.

Plate XLVIII, Fig. 3; Plate LIII, Figs. 1–3.

Fishes of moderate or small size; head a nearly equilateral triangle, measuring about one foot on a side; cranium, maxillary, and mandible similar in character to those of *Dinichthys intermedius*, but only half to two-thirds as large, and the mandible bears *two* subordinate prominences back of the turned up tooth-like extremity; also the posterior end of the cutting edge is set with two or three unequal denticles in place of the series of even, lancet-like points in the same position on the mandible of *D. intermedius*. The anterior ventro-lateral plate is scimiter-shaped, eight inches long by two and a half inches wide, being relatively narrower than the corresponding bone in any other species known.

A series of specimens recently sent to me by Prof. William Kepler throw new light upon the structure of this species and make it necessary to add a few paragraphs to the description already given. These were obtained from the Cleveland shale at the locality in the suburbs of Cleveland from which so many fine things have been procured by Dr. Clark and Professor Kepler—a locality called in my notes Linnville, Brooklyn, and Cleveland. They consist of the greater part of the bony structure of what was probably a nearly mature individual. The parts are somewhat displaced, but the entire cranium with the suborbital plates on either side, and the supra-scapulas articulated to the posterior angles, may all be identified. One mandible and one ventral plate similar to the narrow one figured on Pl. XLVIII, Fig. 3, are also present; and most interesting of all are the disconnected and scattered, but still easily recognizable sclerotic plates. It was not before known that the eye in this species of *Dinichthys* was surrounded by a series of bony plates, though they had been found in connection with the head bones of *D. Gouldii*. In the present species they are trapezoidal in form, of about the same width as in *D. Gouldii*, but only half as long; from which we may infer that more than four were needed to form the ring around the visual aperture, or that the eye was much smaller. On the in-

side they are more or less radiately striate and marked with the furrows of the nutrient vessels; the outside is granular like the exterior surfaces of most of the bones of *Dinichthys.*

The dimensions of the cranium and appendages in this specimen of *D. curtus* are as follows: Length of cranium from occiput to nasal extremity ten inches; breadth between articulations with supra-scapulas, eight inches; breadth between posterior angles of the head, twelve inches; mandibles nine inches long by two and a half inches wide; suborbital plates seven inches long; posterior and flattened portion three and a half by four inches; supra-scapulas, relatively broader than any other species known, three and a half by six and a half inches in area. The mandibles have the general form of those of *D. Terrelli* and are much broader and more massive than those of *D. Gouldii.* Back of the cutting edge the margin is set with two or three denticles of unequal size and just behind the anterior upturned point are *two* triangular prominences where most species of the genus have but a single one

The figures on Pl. LIII represent a mandible, a supra-scapula, and a sclerotic plate, all of natural size.

GLYPTASPIS, nov. gen.

Placoderm fishes of large size belonging to the family Pterichthidæ. The body was protected by numerous thick, bony plates, of which those of the plastron were probably five in number, as in *Pterichthys*, *Coccosteus*, and *Dinichthys.* The middle one is lance-shaped or subrhomboidal, its central portion tuberculated, its margins sloped off and smoothed or striated by the overlap of the lateral ventral plates. The upper part of the body carried a number of lanceolate or ellipsoidal plates, of which the central parts are ornamented, the margins smooth and sloped down to thin edges. From the absence of marks of co-adaptation it seems probable that these plates did not overlap to form a carapace, but were set in the skin like the scutes of the sturgeons. The head plates and dentition are unknown.

More material is wanted to give a satisfactory definition of the structure and relations of this genus, but the plates of the single species known are so striking in appearance, through their strong and characteristic ornamen-

tation, that they will be easily recognized wherever seen. Doubtless the head with its jaws and teeth will soon be found by its indefatigable discoverer, and it will then be possible to give a more complete description of it. Among the other fish remains associated with the plates of *Glyptaspis* in the Cleveland shale are two, of which the jaws and teeth are the only parts yet known, viz, *Diplognathus* and *Mylostoma*, and it is quite possible that the plates of *Glyptaspis* will be found in such relation with one or the other that we may be sure they once belonged together. This is not certain, however, as there are indications from fragments found that the fish fauna of the basin in which the Cleveland shale was deposited contained other genera and species than those already described.

Glyptaspis verrucosus, n. sp.

Plate XIII, Figs. 1, 2.

Ventromedian plate broad-lanceolate, acute at one end, obtuse at the other, fifteen inches long by seven broad; central portion of outer surface forming a halbert-shaped figure coarsely tuberculated or ridged by lines of confluent tubercles, margins beveled to an edge, forming a band an inch or more in breadth on every side; this slope is smooth or striated, evidently by the overlap of other plates, of which probably four surrounded the central one. The median plate, like others forming the armor, is from a quarter to half an inch thick, of dense bony tissue, the tuberculated portion being covered with a sheet of enamel.

A number of plates or pieces of plates ornamented like the ventromedian, and therefore from fishes of the same species, have been found by Mr. Terrell in the Cleveland shale; the first fragment many years ago. They are generally broken and sometimes bear marks of the great teeth of *Dinichthys Terrelli*, evidently the tyrant and terror of the bay or gulf in which the Cleveland shale was deposited.

When entire these plates must have been long-elliptical in outline and unsymmetrical; therefore are not from the median line of the back. The central portion of the outer surface carries the strong and peculiar ornamentation of the ventromedian plate, but this is surrounded by a sloping margin an inch in width which reaches to an acute edge. This margin is

so smooth, the edge so sharp and even, that it seems hardly possible that the plates could have been in contact with each other, but they were probably set in the skin like the scutes of the sturgeons.

None of these plates have yet been found quite entire, but some of them must have been eighteen inches in length by six inches in width; one end was acute, the other truncated, as though they had been set in rows touching and slightly overlapping at the ends.

Genus DIPLOGNATHUS, Newb.

Bones of cranium and body unknown; dentary bones long and slender, flattened, straight, spatulate behind, where originally covered with cartilage; anterior and exposed portions rising into points which diverge from the symphysis, giving a forked extremity to the lower jaw; conical, acute teeth formed from the jaw tissue are set along the outer margin of the mandibles and on the inside of the divergent extremities beyond the symphysis. A deep pit in each dentary bone marks the point of insertion of a powerful ligament, which bound the rami together and prevented splitting.

The remarkable structure of the jaws on which the foregoing description is based is, so far as known, without parallel in the animal kingdom. The dentary bones are produced forward into triangular, divergent points, of which the inner margins are set with sharp, recurved teeth. This formed a kind of forked rake, which must have been a very effective instrument for catching slender, slippery fishes or annelids, and was doubtless used for that purpose.

One pair of mandibles and the anterior half of another are all the relics yet obtained of this fish. These are described and figured in this memoir.

Diplognathus mirabilis, Newb.

Plate XI, Figs. 1–4; Plate XII, Figs. 1–3.

Diplognathus mirabilis, N.; Annals N. Y. Acad. Sci., vol. 1, 1878, p. 188.

Dentary bone attaining a length of eighteen inches by a width of two inches in the widest part; anterior half thickened as in *Dinichthys*, gently rising into an acute point anteriorly, which diverges from its fellow of the

opposite dentary bone to form a forked extremity to the under jaw; upper margin of the anterior half of the dentary bone set with strong, conical, acute, incurved teeth, about fourteen in number, which diminish in size as they ascend the elevated point; five or six conical, recurved teeth are set on the inner side of the triangular extremity of the mandible, filling the space between the point and the symphysis; a broad, roughened depression or pit at the symphysis marks the place of attachment of a strong ligament which united the mandibles; the posterior extremity of the dentary bone is flattened, spatulate, and straight.

The above description was based on the anterior half of a dentary bone found in 1877 by Mr. Jay Terrell in the Cleveland shale in Lorain County, Ohio. After that time no traces of this remarkable fish had been met with until 1886, when Mr. Terrell obtained, in the same formation and in neighboring localities, two complete dentary bones, right and left, of nearly the same size. These are twelve inches long, but differ slightly in proportions, and evidently were derived from two individuals. No other portion of the bony structure of *Diplognathus* has been obtained, unless it shall prove that these jaws belonged with the plates described elsewhere in this memoir and called *Glyptaspis.* But few of these plates have yet been found, and it is evident that, like *Diplognathus*, *Glyptaspis* was a rare fish in the water basin in which the Cleveland shale was deposited.

Although so anomalous in their structure, it is apparent that the jaws described above belonged to a fish that was a member of the family of the Dinichthidæ, since in many respects they resemble the jaws of the different species of *Dinichthys*, *Titanichthys*, and *Trachosteus*, i. e., they are alike in having the posterior extremity flattened and spatulate, evidently once entirely buried in integument, while the anterior and exposed half is more massive, is composed of denser tissue, and rises to a pointed extremity somewhat in the style of a sled-runner. In *Dinichthys* the anterior extremities of the mandibles were much more abruptly curved upward, and served simply as powerful, penetrating and grasping teeth. As in *Diplognathus* the extremities were divergent, but were not provided with teeth on the inside.

Much remains to be learned in regard to the armor of *Glyptaspis*, since only a small number of the plates composing it have been discovered, but

these prove that it was allied to *Dinichthys*, and there is nothing improbable in the supposition that the jaws which belonged to this fish were similar to those I have described under the name of *Diplognathus*. In time this problem will doubtless be solved by the discovery of jaws associated with the armor of *Glyptaspis* or plate armor with *Diplognathus*.

The mandibles of *Trachosteus*, so far as shown in the only specimens known, are strikingly similar to those of *Diplognathus*, and as in these specimens the anterior extremity is wanting, I at one time had a suspicion that it would be necessary to unite these two genera, but on comparing their mandibles it was found that there were marked differences, which proved that they could not be united. Hence we are compelled to say that the jaws of *Diplognathus* cannot be associated with the remains of any other fish found in the Cleveland shale unless it be *Glyptaspis*.

Genus MYLOSTOMA, Newb.

Dipterine Ganoids of large size, of which as yet only the dentition is certainly known; the teeth or dental plates consist of strong and massive tables of bony tissue, becoming more dense and enamel-like toward the triturating surface. They apparently formed several pairs on both the upper and lower jaws. The principal plates of the lower jaw had long-oval or spatulate crowns three to six inches in length by one to two inches wide and half an inch or more in thickness, supported by strong, vertical, spatulate bones, which projected downward and backward, terminating posteriorly in thin, rounded margins. The upper surface of the crown is raised into a more or less prominent tubercle which is situated near the exterior margin and slightly anterior to the middle. Another pair of teeth apparently belonging to the lower jaw are triangular in outline, with one straight and shorter side, where they join and an exterior arched and longer side. In the posterior end of each is a deep notch, apparently for the reception of the blunt-pointed anterior end of one of the larger dental plates described above. The surfaces of these triangular teeth are convex. Possibly other teeth were associated with these to form the pavement of the under jaw, but that is not yet demonstrated.

The dental plates of the upper jaw are tabular and consist of very dense tissue; they probably formed several pairs on opposite sides of the median line; the largest is somewhat triangular in outline, with a concave triturating surface and vertical sides, apparently for co-adaptation to other teeth of the set. Others of these palate teeth are shorter and broader, with one margin concave, apparently for fitting the rounded posterior end of the larger teeth just described. The bases of these teeth or dental plates are flat, and they were apparently attached to the roof of the mouth.

It is probable that we have not yet obtained all the elements in the dentition of this fish, and the parts yet discovered are so peculiar and anomalous as to make it difficult to co-ordinate them satisfactorily with any others hitherto known. The flattened tabular dental plates which I have supposed formed the roof of the mouth have a general resemblance in form and texture to those of *Chimæra*, and it is evident are their analogues and functionally their representatives; still the teeth of the under jaw found with these, and exhibiting the same microscopic structure, differ widely from any portion of the dentition of Chimæroid fishes and show a greater resemblance to the dental plates of the Dipterine Ganoids. They evidently formed pairs, for we have the corresponding teeth of the right and left sides, and though wanting the radiating ridges of the teeth of Ctenodonts, they seem to have occupied corresponding positions. The strong vertical supports on which they are mounted correspond with the splenial bones that carry the inferior dental plates of *Ctenodus*, except that they are flattened vertically instead of horizontally, and probably represent more of the mandible.

The resemblance of the teeth which I have supposed formed the roof of the mouth to those of *Ceratodus* will strike any one who examines them, and no closer analogy suggests itself in the whole range of ichthyic dentition. There is, however, this marked difference, that while in *Ceratodus* there is only one pair of dentary plates borne on the palato-pterygoid bones, in *Mylostoma* there were certainly several pairs of pavement teeth in the roof of the mouth. The spatulate bones which form the supports of the principal dental plates of the lower jaw evidently represent the thin, flattened, smooth, and once buried posterior end of the dentary bone in all of the Dinichthidæ; and, taken by itself, each of these dental plates with its

support may be regarded as the dentary bone of the mandible. But the margins of these triturating plates are smoothed vertically or beveled in such a way as to indicate co-adaptation to other plates. We have seen that one pair, described above, probably fitted on to the anterior extremities of these larger plates, and there may have been others at the sides or behind. Such a division of the dentary bone into distinct parts is not altogether without precedent, for in *Dendrodus* and *Rhizodus* the dentary bones are segmented, each piece carrying one or more of the great, conical, socketed teeth which constitute the formidable dentition of these fishes.

The modifications of structure in the mouths of fishes recent and extinct to give support to pavement or crushing teeth are very varied, as will be seen by reference to the dentition of the *Pycnodonts* among fossil fishes and to the drum, sheepshead, etc., of our living fauna. Among Elasmobranchs the Cestracionts and Rays present an almost infinite variety in the form and arrangement of the teeth adapted to crushing mollusks and crustaceans. But if we are correct in considering *Mylostoma* as a member of the family of the Dinichthidæ, we have in it an example of extreme specialization in another direction, but no less marked and surprising than in *Dinichthys* and *Diplognathus.* In a former notice of this genus I have compared its dentition with that of *Dipterus*, *Palœdaphus*, *Ctenodus*, and *Ceratodus*, and the points of resemblance are sufficient to justify the inference that they were all related.

In regard to the cranium and external defenses of the body in *Mylostoma* we are yet in ignorance, although the number of dental plates collected by Mr. Terrell is already considerable. I have elsewhere described a portion of the body plates of a large Placoderm, *Glyptaspis*, found in the Cleveland shale, with which no jaws and teeth have yet been connected, and have suggested that either the jaws of *Diplognathus* or the teeth of *Mylostoma* might have belonged to this fish. It is hardly probable that, while living in a community so generally armor-clad as the Dinichthidæ were, and with reason, that either *Mylostoma* or *Diplognathus* was without some protection of this kind; and though neither of these genera could have contended successfully with the formidable armament of *Dinichthys Terrelli*, they would have been less entirely at his mercy if the vital portions of the body were

shielded by bony plates. We can imagine that *Diplognathus*, if swift in its movements, might have found parts of the body of *Dinichthys* that were penetrable by the points of its mandibles, but *Mylostoma* was provided with no means of offense, and, unless armor-clad, would have had no safety but in flight.

The plates of *Glyptaspis* which we have found are often broken as though by violence, even where composed of dense, bony tissue half an inch or more in thickness, and the surfaces of the plates, at least in one case which has come under my observation, show deep furrows, that have been traced by the points of the premaxillaries or mandibles of *Dinichthys*.

MYLOSTOMA TERRELLI, Newb.

Plate XIV, Figs. 1, 2.

Mylostoma Terrelli, N.; Trans. N. Y. Acad. Sci., vol. 2, 1883, p. 147.

Principal inferior dental plates in pairs, each of which is spatulate in outline, with one margin nearly straight where it joined its fellow, the other strongly arched; length six to seven inches by two inches in greatest breadth; crown composed of dense, enamel-like tissue eight lines in thickness at the front and gradually thinnin gtoward the narrow posterior end; triturating surface punctate or vermicularly roughened, slightly arched from front to rear, and rising into a low rounded boss near the external margin, where the tooth is broadest, and about one-third the length of the crown from its anterior extremity. The crown is supported below by a strong, bony keel, which begins at the anterior fourth of the length and gradually descends backward until it has a width of two and a half inches, terminating in a thin irregular margin twelve to fifteen inches from the anterior extremity of the crown.

Of this large species only a single specimen has yet been discovered. This includes the crown complete with a part of the splenial (?) bone on which it was supported. The entire dentary bone must have been fifteen to eighteen inches in length.

This specimen is figured on Pl XIV, views of both the side and crown surfaces being given.

Formation and locality: Cleveland shale; valley of Vermilion River, Erie County, Ohio. Collected by Mr. Jay Terrell.

Mylostoma variabilis, Newb.

Plate XV, Figs. 1–5a; Plate XVI, Figs. 1–4.

Mylostoma variabilis, N.; Trans. N. Y. Acad. Sci., vol. 2, 1883, p. 146.

Inferior dental plates probably of several forms, the larger ones long-ovoid in outline, three inches long by one and an eighth inches wide in the broadest part, supported on and anchylosed to a vertically flattened, spatulate bone eight or ten inches long by two inches wide; the crown is composed of dense bony tissue half an inch in thickness anteriorly, but thinner near the narrow posterior end; crown surface dense and enamel-like, granular or roughened with a vermicular marking, rising near the middle and on the outer side into a strong oblique tubercle or boss. Another pair of teeth, probably joining these anteriorly, are long-triangular, with the posterior ends obliquely notched, apparently to receive the obtuse points of the larger teeth. These triangular teeth are arched above and the sides are prolonged downward in root-like wings which were once buried in the integument. Possibly other teeth were joined to these to make up the pavement of the under jaw. Considerable diversity is shown in the character of the crown-surface in corresponding teeth. Three of these, nearly of the same size, show marked differences, viz: One bears a rudimentary irregular boss near the outer angle; another, from the opposite side, rises into a strong, furrowed, depressed, obtuse tubercle half an inch in height; while the third, corresponding in position with the last, is a little shorter and broader, and the tubercle is laterally deflected and compressed. Still another and very imperfect tooth of smaller size has the crown elliptical in outline, carrying a blunt, furrowed tubercle, relatively larger than that on either of the others. All these teeth just described are convex above, and probably formed part of the dentition of the lower jaw.

The dental plates of the upper jaw form several pairs, of which the central and largest are rudely triangular in outline, with a flattened or concave triturating surface, bearing, as do some of the inferior teeth, evidences

of wear. The surface of attachment to the cranium of these dental plates is flat or concave and somewhat rough, from the coarse cellular tissue of the bone; the sides are straight or beveled, apparently for co-adaptation, and by this character favor the conclusion that the dentition consisted of many pairs of plates, constituting a tessellated pavement; the crowns of the teeth below being convex, those above concave.

Formation and locality: Cleveland shale; Sheffield, Ohio. Collected by Mr. Jay Terrell.

TRACHOSTEUS, nov. gen.

Placoderm fishes of medium size, belonging to the family of the Dinichthidæ. Body inclosed in defensive armor, consisting of a number of large, but relatively thin, bony plates, of which the outer enameled surface is thickly set with high conical tubercles, that are acute, rounded, or cupped at the summit. The spaces between these tubercles are radiately lined. The form of the head is not distinctly shown in the only specimen yet found; the plates of the body consist apparently of one large oblong dorsomedian with several smaller and irregular lateral plates united with each other and the dorsal by overlap joints. The under jaws, as in all of the Dinichthidæ, consisted of cartilaginous angular and articular parts with dense bony dentary portions. The dentary bones are nearly straight; the posterior end is spatulate and was evidently once covered; the anterior third or exposed portion carries a row of slender, conical, acute teeth along its upper margin; premaxillaries subtriangular in outline, the anterior face arched, and terminating below in an acute point; the posterior edge horizontal, and carrying slender, pointed teeth, which matched with a portion of those of the mandible. The eye-orbits are relatively large and round, and are encircled by a ring composed of four sclerotic plates, of which those of one side are much narrower than the others. The exterior surface of these plates is in part tuberculated like the cranial and dorsal plates, in part smooth or radiately striated.

Only one specimen of the fish to which the above name is here given has yet been found, and of this the parts, though all present, are so confused, that it is not possible to describe them fully. The ornamentation of the

surface of the plates is, however, so peculiar and strongly marked, that it will serve for the identification of even a fragment wherever found. The affinities of the genus are apparently closest to *Aspidichthys* of the Huron shale, but more material of both is needed for a satisfactory comparison.

Trachosteus Clarkii, n. sp.

Plate XLII, Figs. 1–8.

The characteristics of this species are for the most part given in the generic description, and its more minute and specific features can only be detailed when other individuals shall have been found. The dimensions of that which has served as a basis for the generic description can be best inferred from the under jaws, of which the dentary bones were apparently about twelve inches in length. Unfortunately the anterior extremities are somewhat broken, and therefore the exact length and the character of the symphysis cannot be determined. The posterior portion of each is straight, about an inch in width, blunt-pointed or rounded and flattened at the end; the anterior portion is nearly smooth without and within, about an inch in width, and carries on its upper margin acute, rather slender, teeth, which are three-eighths of an inch in length, and are composed, as in all other members of the family, of indurated enamel-like jaw-tissue. The premaxillaries are about an inch and a half in length, the anterior portion arched, excavated, and pointed, as in *Dinichthys.* The eye-orbit is one and three-quarters inches in diameter and nearly round. The inequality in the breadth of the sclerotic plates and the tuberculation of some part of the external surface will serve at once to distinguish the eye of this fish from that of *Dinichthys Gouldii*, which occurs in the same beds. The external diameter of the ring of sclerotic bones is about the same in both, viz, four inches, but in *Dinichthys* the orbit is elliptical and all the orbital plates are of about equal breadth.

The outlines of the dorsal plate cannot be fully made out from the single specimen yet known, but it was apparently oblong, about fifteen inches in length by ten inches broad; the anterior (?) lateral plates are unsymmetrically ovoid in outline, about six inches long by five broad.

Formation and locality: Cleveland shale; banks of Rocky River, below Berea, Ohio. It was there discovered by Dr. William Clark, for whom the specific name is given. The unique specimen which formed the base of the above description is in the geological museum of Columbia College.

CTENACANTHUS COMPRESSUS, Newb.

Plate XXIII, Figs. 4–4[b].

Ctenacanthus compressus, Newb.; Annals N. Y. Acad. Sci., vol. 1, 1878, p. 191.

Spine six to ten inches long by one and a half inches wide; much compressed; strongly arched above; anterior margin smooth; posterior flattened, with a well-marked rounded ridge along the central line; upper half of posterior face thickly set with conical recurved teeth; exposed portion wholly covered with fine longitudinal ribs, which are highly ornamented by closely approximated transverse lines; pectination finest on middle and lower portion of sides.

The flattened, highly compressed form of this spine will serve to distinguish it at a glance from any other species of the genus. The ornamentation is crowded and exact, and the organ must have been in life decorative as well as useful.

I have recently received from Dr. William Clark a nearly complete spine of this species, only the unornamented base being absent. It is about nine inches long, and must once have been two inches longer. It is much curved backward, but more uniformly than the spines of *Ct. Clarkii*, N. The ornamentation is very similar to that of that species, but the form is much more compressed. It is possible, however, that the two species may have been the anterior and posterior dorsal defenses of the same fish.

Formation and locality: Cleveland shale; Sheffield, Lorain County, Ohio. Found by Mr. Jay Terrell. Type specimen in the cabinet of Columbia College.

CTENACANTHUS CLARKII, n. sp.

Plate XXVI, Figs. 2, 3.

Spines six to eight inches long, about one inch broad at the base of the ornamented portion, and five-eighths of an inch in greatest thickness; poste-

rior face excavated in a broad, shallow sulcus, which is bordered above by many acute, conical teeth; anterior margin subacute, nearly straight below, strongly curved above; sides gently arched, wholly covered with relatively fine and uniform, enameled, pectinated ridges, coarser toward the middle, where there are some twenty-five on each side, finer toward the base, where there are about forty on a side. The pectination of these ridges is everywhere fine, but much closer near the base, where it forms a marked character; margin of enameled surface at base curved upwards and backwards, reaching the posterior face about the middle; medullary cavity opening posteriorly up to the middle of the spine.

In its general aspect this beautiful spine is not unlike *Ctenacanthus speciosus*, St. J. & W.,[1] but it is less broad and compressed, more acute and curved above, and the lateral ridges of the ornamented portion are much more closely pectinated. In size and general form it also resembles *Ct. vetustus*, N.,[2] but is thicker below, more acute, and curved above, and the longitudinal ridges are very much more numerous and more closely pectinated. The ornamentation of the sides is more like that of *Ct. compressus*, N. (Pl. XXIII, Fig. 4), but it is much less compressed, and the transverse raised lines which form the pectination are closer. The posterior face is also without the central ridge which occurs in *Ct. compressus* and many other spines of *Ctenacanthus*. On the whole, this is one of the most exact and beautiful species of the genus, and I take pleasure in dedicating it to Dr. William Clark, who discovered it in the Cleveland shale near Berea, Ohio.

Hoplonchus parvulus, Newb.

Plate XXV, Fig. 5.

In the Palæontology of Ohio, volume 2, page 55, pl. 59, fig. 3, a small spine from the Cleveland shale is figured and described under the name of *Ctenacanthus parvulus*. In the notes on this fossil it is said: "This little spine is referred to *Ctenacanthus* with some doubt, as the longitudinal ribs show no tubercles or scales such as are usually found on the spines of this genus. It agrees with them, however, in the generalities of its form and markings, and scarcely affords material for the creation of a new genus."

[1] Geol. Survey Illinois, vol. 6, p. 424, pl. 14, fig. 3. [2] Palæontology of Ohio, vol. 1, p. 326, pl. 35, fig. 3.

Since the date of that report (1875), Mr. J. W. Davis, in a paper published in the Quarterly Journal of the Geological Society of London for May, 1879, "On Some Fish Spines and Teeth from the Lower Coal Measures," figures and describes a number of small dorsal spines which should evidently be associated with that under consideration. To these he has given the generic name of *Hoplonchus*, and his species is *Hoplonchus elegans*. His specimens come nearer to *Ctenacanthus* than that from the Cleveland shale, as according to his description some of the longitudinal ridges are tuberculated near the base. Most of the striæ, however, are smooth, and the denticles of the posterior border are like those of our specimen, relatively large and widely spaced.

Cladodus concinnus, Newb.

Plate XXI, Figs. 9, 10.

Cladodus concinnus, N.; Palæontology of Ohio, vol. 2, p. 48, pl. 58, fig. 8.

Teeth from one-half an inch to an inch in height and breadth; base narrow boat-shaped, with pointed extremities; central cone compressed, with sharp edges; posterior face flat or gently rounded; anterior strongly rounded; both striated; lateral denticles generally two pairs, both striated; external pair the larger and divergent.

This beautiful species is noticeable for its compressed double edged and strongly striated cone, its divergent lateral denticles, and its narrow, pointed base. It is unusually elegant in form, and is one of the most highly ornamented of all the species of the genus.

The specimen figured in the Ohio report is much smaller than those since obtained by Mr. Terrell, and it therefore gives a false impression in regard to the average size. Those now shown are selected from a considerable number and fairly represent the species.

Formation and locality: Cleveland shale; Lorain County, Ohio. Collected by Mr. Jay Terrell.

Cladodus Terrelli, n. sp.

Plate XXVII, Figs. 5–7.

Teeth of various sizes, the largest one inch in height and breadth; robust; base narrow, boat-shaped, with rounded lateral extremities; central

cone compressed, with sharp edges; both faces arched, though unequally; anterior face marked by four to six strong longitudinal costæ, reaching from the base to the upper third, which is smooth and highly polished; lateral denticles, two on either side, exterior pair much the larger, coarsely costate.

The remarkably coarse ridges of the anterior face of the central cone, together with the size of the teeth, will serve to distinguish this from any species before described. Some of the teeth of smaller species of *Cladodus* have a few coarse ridges on the posterior or anterior face or both, such as *C. carinatus*, described in this memoir; *C. costatus*, N. & W.[1] etc.; but none of these are likely to be mistaken for the species under consideration.

A large number of teeth of this species have been obtained by Mr. Park Terrell from the Cleveland shale in the valley of Black River, Lorain County, Ohio. About seventy-five of these were lying in contact or so closely approximated that they may be regarded as belonging to the dental series of one fish. These show great differences in size, some being an inch in height and breadth, while others are not more than one-quarter of that size. Between these extremes there is a gradation in size, but all are essentially alike in form and markings; having like characters and found in such relations, it is certain that they belonged to one fish.

An interesting fact in connection with this set is that many of the teeth have the central cone truncated by wear. This means that the teeth of *Cladodus* were more permanent than those of most of our modern sharks. Apparently a large number were in service at the same time, and they remained for the most part in position and effective during the life of the individual.

A jaw of a small species of *Cladodus* (*C. Pattersoni*) found at Vanceburgh, Ky., still carrying teeth, shows ten or more rows set alternately, and covering the arch of the jaw just as do the crushing teeth of *Rhynchobatus*.

The figures now given represent three medium-sized teeth, one of which is slightly, another much worn, the third truncated by use.

The species is dedicated to Mr. Park Terrell, principal of the Institution for the Dumb and Blind at St. Augustine, Fla. He was formerly the com-

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[1] Geol. Survey Illinois, vol. 2, p. 27, pl. 1, fig. 13.

panion of his father, Mr. Jay Terrell, whose name is so frequently mentioned on these pages, in his fossil hunting expeditions, and shared in his enthusiasm and success.

CLADODUS TUMIDUS, n. sp.

Plate XXVII, Figs. 8, 9.

Teeth broad and low, transverse length one inch, height of central denticle half an inch, base half an inch wide from front to rear, slightly curved, ends rounded; crown carrying three denticles, the central one robust, much recurved, rounded and flattened above perhaps by wear, finely striated in front and rear; lateral cones relatively large, abruptly conical, strongly recurved, striated throughout, subacute.

But a single tooth of this species has so far been found. It was obtained by Mr. Jay Terrell in the Cleveland shale at Sheffield, Ohio. Others will be needed before the species can be fully and satisfactorily defined, but it is evident at a glance that this is quite different from any of the species of *Cladodus* which have been found in the Cleveland shale and from all that have been described from other formations. Its marked characteristics are the shortness and strength of the cones and the fine striation which covers the entire surface of each. In the specimen before us the central cone has evidently been somewhat worn, and from its great curvature the wear has not produced a blunt point as in *C. concinnus* and *C. Terrelli,* which have straight cones, but has worn off the anterior portion of the summit obliquely, so as to leave a rounded but acute extremity. The characters which have been cited will serve to distinguish it from any others with which it is likely to be compared. The small number of the cones, their recurved form, tumid aspect, and finely striated surfaces, with the narrow curved base, will serve to identify it wherever found.

CTENODUS WAGNERI, n. sp.

Plate XXVII, Fig. 30.

Inferior palatal teeth ovate in outline, three inches four lines long by two inches three lines wide; strongly arched, rising one inch three lines at highest point when resting on a level surface; crown traversed by seven strongly marked ridges, separated by furrows of similar triangular section.

Of the ridges the anterior is strongest, the others diminish gradually until the last is barely discernible. The interior and middle portions of the ridges are smooth and moderately acute; the outer third, which is much broader and strongly curved downward, is marked by a series of transverse furrows, which produce first rounded tubercles, and then, as the ridge becomes broader, a series of transverse, flattened, elevated bands.

The splenial bone on which the tooth is set projects posteriorly two inches three lines, is comparatively thin and flat, one inch six lines broad at its widest part, and excavated posteriorly on the outside by a broad shallow notch, which forms with the interior curved edge an acute terminal point.

This fine tooth, the largest species yet known of the genus, resembles in the number and relative size of its ridges *Ctenodus obliquus* and *Ct. monoceros*, from the Northumberland coal field of England, but is at once distinguishable from them by its greater size and the broad, transversely banded ridges.

No portion of this fish has been found except a single inferior dental plate attached to the splenial bone. This was obtained by Mr. Frank Wagner from the Cleveland shale, in the eastern suburbs of Cleveland, Ohio, and the species is dedicated to him.

PHŒBODUS POLITUS, n. sp.

Plate XXVII, Figs. 27–28[a].

Teeth small, robust, breadth between tips of lateral cusps six to twelve millimeters, height from four to eight millimeters, base broadly elliptical, thick, with a strong bi-lobed, pad-like prominence in the middle of the upper surface, concave below, with a narrow arch beneath the cusps; cusps three, of nearly equal size, with minute rudimentary ones in the angles between them, all strongly recurved, flattened in front with salient, acute angles, rounded behind; surface smooth and polished, or bearing a few short, coarse striations.

We have in these little teeth an important addition to the catalogue of fossil fishes found in Ohio, as they represent a generic group extremely rare elsewhere, and now for the first time met with there. It is one also which

has interesting relations with *Cladodus* on the one hand and *Diplodus* on the other; constituting in some sort a connecting link between them. In *Cladodus* the central cusp is always largest and often greatly preponderates over the lateral ones. In *Diplodus*, on the contrary, the lateral denticles are always very much larger than the central, and this latter is not unfrequently quite obsolete. In *Phœbodus*, however, the crown supports three cusps which are of nearly equal size.

The only other teeth known similar to these are those of which the name of *Phœbodus Sophiæ* has been given by St. John and Worthen,[1] and obtained from the middle Devonian of Waterloo, Iowa. From that species ours may be readily distinguished by its larger size and its more elongated, recurved, and equal cusps. The concave base is also somewhat notched posteriorly in our species, and instead of a double pad under the anterior border it has a narrow and accurately defined arch.

The teeth which formed the basis of the above description were found by Messrs. Frank Wagner and Jay Terrell in the Cleveland shale near the mouth of Black River, Lorain County, Ohio. They exhibit considerable range of size, the larger being twice as high and broad as the smaller, and in the larger teeth the polished surface of the cusps is free from striations, while in the smaller form there are a few relatively coarse raised lines on the anterior face of the cusps and base. In other respects they are so much alike that it has not been thought best to distinguish them by different specific names. Their affinities to *Cladodus* are shown by the general form of the base and by the pad-like prominence which occupies the central portion of its upper surface. This feature is quite common among the species of *Cladodus*, but the teeth under consideration are distinguished from all members of that generic group by the great development of the lateral cusps, which are perhaps a little larger than the central one.

ACTINOPHORUS, nov. gen.

Tile-scaled Ganoids, of medium or large size, long and slender; body cylindrical; head pointed, bony; teeth numerous, conical, acute; fins without fulcra, delicate, many-rayed; scales narrow, quadrangular, thin.

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[1] Geol. Survey of Illinois, vol. 6, p. 251, pl. 1, figs. 14–14[d].

More material is needed before the fishes of this genus can be accurately described and their relations with other recent and fossil forms determined. The details of the head plates cannot be made out from the specimens yet obtained, since the bony structure of the cranium readily exfoliates, the outer surface adhering firmly to the matrix, the plates and bones being thus split and their surfaces and outlines lost. So far as we can judge from this material of the genus *Actinophorus* it would seem to be most closely allied to the Palæoniscidæ, and yet an aberrant member of the group of the Lepidosteidæ, occupying an intermediate position between *Palæoniscus* and the Chondrosteidæ. The absence of fulcra is perhaps not complete, as they may be carried by the upper lobe of the caudal fin, a character not shown in the specimens before us; but this is not a family, but rather a generic character, for within the family of the Palæoniscidæ the genera *Palæoniscus, Eurynotus*, etc., have the fins all bordered with fulcra, while *Platysomus* is without them. None of the fins are lobate, and therefore it is not a Crossopterygian. It is to be expected that when better specimens of this fish shall be obtained and we are able to complete our description of it, it will be found to hold important relations to the other described Palæozoic tile-scaled Ganoids, and will perhaps become the type of a new family.

ACTINOPHORUS CLARKII, n. sp.

Plate XLIX, Figs. 1, 1[a].

Body slender, about two feet in length by two and a half inches in diameter at the pectoral fins; head conical, pointed, well ossified, seven to eight inches long, branchiostegals numerous; pectoral fins broadly conical, somewhat falcate, three inches long by one and a half wide, containing about sixty fine, parallel, ossified rays; anal fin eighteen inches from muzzle, relatively small, triangular in outline; caudal strongly heterocercal; dorsal unknown; scales oblong, two to three millimeters wide by five millimeters long, thin and delicate; body long-fusiform or cylindrical, as broad as high.

This peculiar fish constitutes one of several discoveries recently made by Dr. William Clark, of Berea, in the Cleveland shale at Brooklyn, Cuyahoga County, Ohio. He has obtained parts of several individuals, but they

seem to have been of delicate structure, and their preservation is somewhat unsatisfactory. The most striking feature presented by these fishes is the long cylindrical body, which is generally found lying upon the back with the pectoral fins broadly extended. These are remarkable for the great number of fine bony rays which traverse them, and which seem to have been rarely jointed. The habits of this fish were undoubtedly carnivorous, and judging from the long pointed head and slender body it must have been very swift in its motions. The affinities, as has been mentioned, are probably with *Palæoniscus*, but it differs from all the species of that genus in the absence of fulcra from the pectoral, anal, and perhaps the dorsal and caudal fins.

ASTEROPTYCHIUS ELEGANS, n. sp.

Plate XXV. Fig. 4.

Spine six inches in length by four lines wide in the broadest portion lower half nearly straight, upper portion gently curved backward; basal or buried portion about one inch in length, conical in form, finely and irregularly striated; angle between plain and ornamented surface 45°; section a compressed triangle; enameled portion traversed by strongly marked, continuous, arched, and smooth ridges, eight in number at the base, six within an inch of the summit. These ridges are separated by narrower furrows which are longitudinally striated, and toward the summit each is set with a row of tubercles; posterior angles bearing relatively strong denticles throughout nearly the entire length; above, these are hooked downward; in the lower part of the spine they are triangular.

Of this beautiful spine I have two specimens, of which one is quite complete. It is remarkable for the symmetry of its form and elegance of its ornamentation. It would doubtless be classed by all palæontologists as a species of *Asteroptychius*, and may perhaps serve as a fair representative of that genus, although the longitudinal ribs are relatively wider and the furrows much narrower than in the type. Of described species it is perhaps most like *A. St. Ludovici*, St. J. & W.,[1] the size and form being nearly the same, but it may be at once distinguished from that species by the teeth,

[1] Geol. Survey Illinois, vol. 6, p. 437, pl. 16, figs. 3–4 s.

which are much more widely separated and are relatively larger; also by the ornamentation, in which the longitudinal ridges are relatively wider and fewer in number.

Formation and locality: Lower Carboniferous sandstone; (Waverly), Grindstone City, Mich. Collected by Dr. Charles Rominger.

GYRACANTHUS INORNATUS, n. sp.

Plate XXIII, Fig. 5.

Spine large, slightly curved, laterally compressed with an elliptical section, both edges being rounded; surface markings light, consisting of fine longitudinal striæ visible over most of the surface, and parallel, oblique, incised lines, which occupy the sides and converge toward the anterior border.

Only the upper half of one of these spines and the point of another are yet known. The larger specimen is very obtuse, evidently much worn and rounded by use, as the spines of other species of *Gyracanthus* so frequently are. The sides are also worn, and the oblique lines which once for the most part covered them, never being strong, are nearly obliterated. The point of another spine on the same block of stone is rounded in section and acute.

The most striking feature in these spines is their nearly smooth surface and the single set of oblique lines on the sides. Usually in *Gyracanthus* there are two sets of these lines, crossing at right angles and producing a rasp-like surface.

Formation and locality: Waverly group; Wayne County, Ohio.

CLADODUS ROMINGERI, Newb.

Plate XXVII, Fig 10.

Cladodus Romingeri, N.; Palæontology of Ohio, vol. 2, p. 49.

Teeth small, breadth of base seven lines, height of median cone five lines; central cone flattened behind, deeply sinused at base, anterior face rounded; lateral cones two pairs, with sometimes a rudimentary one at the base of the central cone; outer pair slightly less in size than the inner ones; surface of both central and lateral cones strongly striated.

This species resembles *C. acutus* and *C. mirabilis*, Ag.,[1] but differs from both in having the interior pair of secondary cones as large as the outer pair, or even larger; in this respect it is unlike any other species known to me except *C. Hertzeri*.[2]

C. Romingeri was briefly described in the Palæontology of Ohio, but no figure was there given of it.

Formation and locality: Waverly sandstone; Battle Creek, Mich. Collected by Dr. Charles Rominger, to whom it is dedicated.

MAZODUS, nov. gen.

Teeth of Elasmobranch fishes often of large size, thick and massive, with an ovoid, elliptical, or angular outline; upper surface arched in both directions, smooth or finely granulated; under surface concave, coarsely pitted, and variously furrowed and lobed; sides marked by irregular, often pustulous ridges; interior similar throughout, showing irregular, vertical, calcigerous tubes or columns closely compacted into a dense, hard, and enamel-like tissue.

The objects which form the basis of the above description are peculiar and their nature and functions are somewhat problematical. These specimens, from the Waverly of Ohio, evidently belong to a group which includes the so-called teeth of *Helodus rudis* of Agassiz and McCoy, and the peculiar specimen called *Petrodus ? pustulosus*,[3] N. & W. They all present some characters which are not found in other fish teeth, and which at one time led me to consider them as dermal ossicles, viz: First, the arched upper surface is granulated or pitted in quite a different way from that of the teeth of *Psammodus* and all allied genera. Second, they are composed of dense enamel-like tissue throughout, with no division into crown and base, one enamel and the other bone, such as we find in all known crushing teeth of Elasmobranch fishes. Third, the sloping sides are marked with irregular, often tuberculated ridges, which are absent from the borders of all other unmistakable fish teeth, and which closely resemble the markings on the sides

[1] Poissons Fossiles, vol. 3, pp. 197, 199, pl. 22, figs. 9, 12–21.

[2] Palæontology of Ohio, vol. 2, p. 46, pl. 57, figs 5, 5a.

[3] Geol. Survey Illinois, vol. 4, p. 369, pl. 2, figs. 5, 5a, pl. 3, fig. 6.

of the objects which are described by McCoy under the name of *Petrodus* and now thought to be dermal tubercles. Yet they are so large and massive that they present in this respect little similarity to any hitherto known tubercles, and one of the specimens before us has the upper surface peculiarly flattened as though by wear. Hence I have thought best to consider them the crushing teeth of Elasmobranch fishes, and perhaps allied to *Helodus*, as defined by Agassiz and McCoy.

Since the above description was written a large amount of additional material bearing on this subject has been obtained by Prof. William Kepler, of Berea, Ohio, who has kindly put it into my hands for study. This material consists of a number of the teeth of *Mazodus* and the jaws which supported them. They were found dismembered, but in close proximity, and intermingled so that there can be no reasonable doubt that they belonged to one individual, and they throw much light on the structure and relations of the genus. The jaws were composed of prismatic cartilage, which in virtue of the special duty they performed were more ossified than other portions of the skeleton, and hence were firmer and less perishable. I have frequently found this condition of preservation in the jaws of *Diplodus* in the Coal Measures and *Cladodus* in the Waverly shales, the rami separated, the teeth sometimes in position, oftener scattered about in immediate proximity to them. As in all such cases, the jaws are flattened and distorted, but retain much of their substance and approximately their outlines.

The mandibles of *Mazodus* are seven to eight inches long and an inch and a quarter to one and a half inches wide. They show on the upper surfaces depressions which correspond to the position of the teeth. Of these, ten were found grouped together, all in contact and some of them in their relative positions. A larger number evidently composed the dental series, but the others were lost. Those preserved show a great diversity of size and form, the larger and more angular teeth having several smaller ones, and these more elliptical in shape grouped around them. How many composed the complete dentition we have as yet no means of knowing, but those found in this group apparently form but a part of the set belonging to the under jaw.

This discovery removes all doubt in regard to the character of the organs, and shows that *Mazodus* was an Elasmobranch fish, with strong pavement teeth, fitted for crushing mollusks and crustaceans, or for triturating vegetable tissues; a Shark, perhaps allied to *Psammodus*, but differing from that genus in the pattern formed by the pavement teeth, and still more in their anatomical structure.

MAZODUS KEPLERI, n. sp.

Plate XXI, Figs. 1–3.

Teeth of various sizes and shapes, largest two and a half inches long by two inches wide and half an inch or more in thickness, outline pentagonal or subtriangular, anterior angle subacute, lateral angles prominent, posterior angles obtuse and rounded, with a deep sulcus between them, or united to form an arched posterior extremity; upper surface arched in both directions; when unworn, granulated or pitted; under surface slightly concave, coarsely pitted, and more or less lobate or tubercled; sides beveled or arched, and marked by irregular furrows, separated by pustulous or tumid ridges; whole surface polished; substance dense and enamel-like. The smaller teeth were arranged around the larger, and are trapezoidal, subtriangular or elliptical in outline, and from half an inch to an inch in diameter.

The angular outlines of these teeth will at once distinguish them from those with which they must be generically united, viz, *Helodus rudis*, Agassiz,[1] and McCoy,[2] and J. W. Davis,[3] as also with that described and figured in the Geology of Illinois.[4]

The smaller of the two specimens first found (Fig. 1) is absolutely complete in all its parts; the surface being highly polished and having suffered no wear. The upper surface of the larger specimen is less perfect in its preservation, and shows a double depression, which seems to be the result of attrition.

The under surface of these teeth is concave and peculiarly pitted and furrowed; that of the larger one somewhat lobed, and showing considerable

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[1] Ann. Nat. Hist., 2d series, vol. 2, p. 123.
[2] Brit. Pal. Fossils, 1854, p. 631, pl. 3, fig. 4.
[3] Fossil Fishes Carbonif. Limestone, p. 157, pl. 59, figs. 11, 11^a.
[4] Vol. 4, p. 369, pl. 2, figs. 5, 5^a.

similarity to the under surface of the brain of certain animals. It is evident from these characters that they did not rest on any hard, smooth substance, like the jaw which supports the flattened teeth of *Psammodus*, etc., and we must conclude that they were set upon or implanted in comparatively soft tissue.

Formation and locality: Base of Cuyahoga shale; immediately over Berea grit, Berea, Ohio. Collected by Dr. William Clark and Prof. William Kepler.

Ctenacanthus angustus, n. sp.

Spine ten inches long by one inch wide at broadest part, gently and uniformly arched; laterally compressed; exposed portion occupied by relatively few and broad closely pectinated ridges, of which the strongest, of double average width, forms the anterior margin; this is annulated by closely set transverse lines, while on the lateral ridges the cross lines are slightly oblique, rising backward; the ridges are about twelve in number on each side at the middle of the spine.

This species, by its more slender form and few strong enamel ridges, may be distinguished at a glance from *Ct. Clarkii*, N., with which it is associated, and these features serve also to separate it from most others known. In general form it is not unlike *Ct. formosus*,[1] N., but it is somewhat more robust and has not half the number of longitudinal ridges. From *Ct. furcicarinatus*, N. (loc. cit.) it is also separated by the latter character, though the pectination of the ridges is similar.

Formation and locality: Berea grit; Berea, Ohio. Collected by Dr. William Clark.

Section E.—Fishes of the Carboniferous Limestone.

The central member of the Carboniferous system—the Mountain Limestone of England, the Bergkalk of Germany, the Calcaire Carbonifère of France, the Sub-carboniferous or Lower Carboniferous limestone of American geologists—has been described in general terms on the preceding pages. Since it is a marine deposit of great thickness, and therefore the evidence

[1] Palæontology of Ohio, vol. 2, p. 53. pl. 59, fig. 1.

of an immense lapse of time at an age of the world when fishes had become numerous and diversified, it is not surprising that they have left here a voluminous record. Though Amphibians had already made their appearance, as we learn by the foot-prints on Lower Carboniferous rocks, fishes were still the ruling dynasty of the animal kingdom, and had not yet encountered the rivalry of the powerful aquatic reptiles of the Reptilian age, or the mammals of the Tertiary. In the Devonian they had the ocean, lakes, and rivers all to themselves, and with abundant food and no formidable enemies, they multiplied rapidly and soon had taken complete possession of the world of waters. In the Carboniferous age they had been modified and specialized until some of them were adapted to all its conditions, and had taught themselves to capture and digest all kinds of food that the seas contained.

Almost daily additions are made to the list of fishes found in the Carboniferous limestone, and it is evident that we have much yet to learn of its fish fauna, but already the names of the species described from this formation compose a longer catalogue than that of any other geologic system, perhaps indeed of all others. When we combine the contributions to its ichthyology made by Agassiz, Portlock, De Koninck, Von Beneden, Egerton, McCoy, Davis, Worthen, St. John, and the writer, we shall find that they embrace nearly one-half the literature of fossil fishes. In the Monograph of the "Fossil Fishes of the Carboniferous Limestone Series of Great Britain," by Mr. James W. Davis,[1] one hundred and sixty-three species are enumerated, while in volumes 2, 4, 6, and 7 of the Illinois Geological Survey three hundred and ninety-one species of fishes are described by Mr. St. John and myself, of which three hundred and thirty-three are from the Carboniferous limestone and Kinderhook group. To these should be added the species described by Dawson,[2] Leidy,[3] and the writer,[4] and we have an aggregate of nearly four hundred species from the Carboniferous limestone of this continent, and about six hundred species from this country and Europe. Of these nearly all are Elasmobranchs, and the descriptions

[1] Scientific Trans. Royal Dublin Soc., 2d series, vol. 1.
[2] Acadian Geology.
[3] Jour. Acad. Nat. Sci., Phila.
[4] Rep. Geol. Survey Indiana for 1878.

are based on teeth and spines which, separating from the cartilaginous jaws and perishable integuments, were with the dermal tubercles scattered broadcast over the sea bottom. In these circumstances it is evident that the number of species has been exaggerated by giving different names to spines and teeth which once belonged together. It is also probable that the species have been multiplied by assigning distinct names to the teeth of different forms which once belonged to a single dental series. Among the Cestracionts, which include a large part of the Lower Carboniferous Elasmobranchs, there is a marked difference between the teeth of the symphysis and those which cover the posterior portions of the jaws; hence it is possible that we have as yet obtained from this formation traces of not more than three hundred different kinds of sharks. This, however, forms a richer Elasmobranch fauna than that which inhabits our present seas; the number of living species of Sharks, Rays, and Chimæras being, according to Dr. Gunther, only about two hundred and eighty.

Although we probably have as yet but a fraction of the fish fauna of the Carboniferous seas represented in our collections, we certainly have enough to give us a good idea of its zoological character and relations.

In reviewing the material before us we find an almost total absence of the Placoderms and scaled Ganoids, which gave character to the fish fauna of all bodies of water, salt or fresh, in the Devonian age. Comparing the fishes of the Corniferous with those of the Mountain limestone, the difference is surprising. In the first are many dermal tubercles, some spines (*Machæracanthus*), and very rarely one of the pavement teeth of a conchivorous Shark; the greater part of the remains being those of Placoderms and Ganoids. In the Carboniferous limestone, on the contrary, the spines and teeth of Sharks are found in infinite variety, but scarce a plate or scale to record the presence of a Placoderm or a Ganoid. These were, however, not wanting to the fauna of the age; for, as we have seen, along the shores and in the bays where the Waverly strata were deposited—to a large degree synchronous with the lower beds of the limestone—we find abundant remains of the great Placoderms—*Dinichthys*, *Titanichthys*, etc.—and where the conditions were favorable, of many little Palæoniscoid fishes. But all

these had been driven from the open sea, as they were not capable of successfully competing with the varied and powerful Sharks.

Some other interesting things also come out in the study of the Carboniferous Elasmobranch fauna.

Judging from the teeth, which are the most characteristic organs, we may infer that in the Carboniferous age the Elasmobranchs as a whole were far less sanguinary and formidable than now. At least three-fourths of all the species described had crushing teeth, adapted to the trituration of sea-weeds or to breaking the shells of mollusks and crustaceans, and the number of those provided with cutting or piercing teeth was comparatively small. Most of the teeth were considerably like those of the Port Jackson shark, and there is little doubt that, as suggested by Agassiz, this peculiar member of our present fauna is a descendant and a representative of the most numerous and characteristic tribe of Carboniferous Plagiostomes.

That the food of these fishes was generally mollusks, and sometimes those with very resistant shells, is proved by the massive character of the dentition, the pitted or ridged surface of the enamel to prevent the slipping of the objects crushed, and also by the evidences of wear at the places where the greatest mechanical effect was gained.

The simplest form of dentition adapted to crushing was that of *Psammodus,* of which the teeth were quadrangular, from one to three inches square and half an inch to an inch in thickness, composed of solid dentine below and a thick sheet of pitted enamel above. Closely allied to *Psammodus* was *Archæobatis,* of which the teeth are figured on the plates accompanying this memoir. The dentition of this genus formed a pavement of many teeth, of which the largest were six inches long by four inches wide and one and a half inches thick. To prevent the slipping of the objects operated upon by this powerful crusher the enameled surface was roughened by transverse, parallel ridges, precisely as in the living *Rhynchobatus.*

The first deviation from this simplest style of dentition is found in *Sandalodus, Deltodus, Cochliodus,* etc., in which the teeth are of different sizes and forms on the same jaw, and are more or less arched or twisted. The next is *Chomatodus,* in which the teeth were long and narrow, flat or ridged on the upper surface, and placed transversely, like those of the

modern Rays. Another form of crushing teeth is that of *Orodus*, in which the crown rises in a series of hillocks, forming a miniature mountain chain (whence the name), of which the central summit is highest. Of these teeth there is a great variety. Some of them have the crown most elaborately carved and ornamented, and some are of great size; *Orodus ramosus*, of the Mountain limestone, having the mouth filled with a hundred or more teeth that were from two to five inches in length. A closely allied, if not identical, species from the Carboniferous limestone of Illinois was still larger.

A group of Sharks with peculiar cutting teeth—the Petalodontidæ—formed a conspicuous feature in the Carboniferous fish-fauna running through the Carboniferous limestone and the Coal Measures. These had teeth of which the crowns had the form of the blade of a long-handled shovel, and were usually attached to a strong root, that must have been firmly planted in the integuments of the jaw. *Antliodus* is a form related to *Petalodus*, but in the teeth of this genus the root is very small or wanting. In *Polyrhizodus* the crown of the tooth was like that of *Chomatodus*, while the root was divided into a number of lobes. An allied form, *Dactylodus*, had the crown of *Petalodus* and a root consisting of many finger-like branches.

The Sharks with piercing teeth formed the genus *Cladodus* and its allies, which were numerous and wide-spread during all the Carboniferous age. These had teeth with broad semilunar bases, which afforded a firm support to an acute, conical, and usually ancipital central cone, flanked by one or more lateral denticles, of which the exterior pair were largest. Some of the species of *Cladodus* must have been large and formidable fishes; the teeth were in many rows, several hundred in each set, and the central cone was sometimes an inch and a half in length.

The spines of the Carboniferous Sharks have been already alluded to; and they also afford proof of the size of their wearers. Many of the spines of *Ctenacanthus* attain the length of a foot or more, while the great spines of *Phoderacanthus*, described by Mr. J. W. Davis, were more than two feet in length and six inches in diameter at the base.

The following is a list of the genera, with the number of species in each, up to the present time, described from the Lower Carboniferous limestone

in North America. The letters set opposite the names are abbreviations of the names of the describers, as follows: Ag., Agassiz; McC., McCoy; Daw., Sir William Dawson; S. & W., St. John and Worthen; N. & W., Newberry and Worthen; N., Newberry.

Genera.	No. of species.	Genera.	No. of species.
Acondylacanthus, S. & W	6	*Lambdodus*, S. & W	5
Agassizodus, S. & W	4	*Leiodus*, S. & W	2
Amacanthus, S. & W	1	*Leptacanthus*, Ag	1
Anaclitacanthus, S. & W	1	*Lisgodus*, S. & W	3
Antliodus, N. & W	9	*Maracanthus*, S. & W	1
Aspidodus, N. & W	2	*Mesodmodus*, S. & W	3
Asteroptychius, Ag	6	*Oracanthus*, Ag	5
Batacanthus, S. & W	3	*Orodus*, Ag	20
Bathycheilodus, S. & W	1	*Orthopleurodus*, S. & W	3
Bythiacanthus, S. & W	1	*Palæoniscus*, Ag	1
Carcharopsis, Ag	1	*Peltodus*, N. & W	3
Calopodus, S. & W	1	*Petalodus*, Ag	4
Cholodus, S. & W	1	*Periplectrodus*, S. & W	4
Chomatodus, Ag	14	*Petalorhynchus*, Ag	4
Chitonodus, S. & W	4	*Phœbodus*, S. & W	1
Cladodus, Ag	33	*Physonemus*, Ag	7
Cochliodus, Ag	8	*Petrodus*, McC	2
Cœlosteus, N	1	*Platyodus*, N	1
Copodus, Ag	2	*Pnigeacanthus*, S. & W	1
Ctenacanthus, Ag	21	*Psammodus*, Ag	17
Ctenopetalus, Ag	7	*Pristicladodus*, McC	1
Ctenoptychius, Ag	3	*Polyrhizodus*, McC	8
Dactylodus, N. & W	6	*Pœcilodus*, Ag	2
Deltodus, N. & W	16	*Pristodus*, Ag	1
Deltodopsis, S. & W	6	*Psephodus*, Ag	6
Deltoptychius, Ag	5	*Rhizodus*, Ag	1
Desmiodus, S. & W	4	*Sandalodus*, N. & W	10
Drepanacanthus, N. & W	4	*Stenopterodus*, S. & W	3
Erismacanthus, McC	1	*Stethacanthus*, N	2
Eunemacanthus, S. & W	1	*Stemmatodus*, S. & W	7
Fissodus, S. & W	2	*Tæniodus*, S. & W	3
Gampsacanthus, S. & W	3	*Tanaodus*, S. & W	1
Glymmatacanthus, S. & W	1	*Tomodus*, S. & W	1
Gyracanthus, Ag	1	*Venustodus*, S. & W	5
Harpacodus, Ag	2	*Vaticinodus*, S. & W	6
Helodus, Ag	17	*Xystracanthus*, Leidy	2
Homacanthus, Ag	2	*Xystrodus*, Ag	5
Hybocladodus, S. & W	5	Total	347

FISHES OF THE LOWER CARBONIFEROUS ROCKS OF NEW BRUNSWICK.

In the shales associated with the Albert mine at Hillsborough, New Brunswick, an interesting group of Palæoniscoid fishes has been found.

Most of them are small, with highly ornamented scales and head plates, having a marked resemblance to those obtained from the Lower Carboniferous shales of Burdie House and Eskdale, in Scotland, and described by Agassiz and Traquair. They have all been included in the old genus *Palæoniscus*, but in the subdivision of that genus by Dr. Traquair they fall partly into the genus *Rhadinichthys* and partly into *Elonichthys*. The following species have been enumerated:

Palæoniscus Alberti, Jackson.
" *Cairnsii*, Jackson.
" *Brownii*, Jackson.
" *Jacksonii*, Dawson.
" *modulus*, Dawson.

The number of individuals found at this locality is enormous; the surfaces of the shale being sometimes completely covered and the fishes often overlying each other, showing that they were literally buried in heaps. They were probably the inhabitants of a body of fresh water, and were killed simultaneously by thousands in some general catastrophe.

Sir William Dawson has also noticed[1] some remains of fishes found in the Lower Carboniferous rocks at Horton Bluff, New Brunswick, and has described a species of *Rhizodus* (*R. Hardingi*, Daw.,) and one of *Acrolepis* (*A. Hortonensis*, Daw.).

Dr. Joseph Leidy has described and figured[2] a number of fish teeth from the Carboniferous limestone of Illinois and Missouri; these include several species of *Cochliodus*, which would now be referred to *Deltodus* and *Psephodus*, and one species of "*Ctenoptychius*," which is a *Dactylodus* reversed.

William McAdams, of Alton, Ill., has recently sent to me some large fish jaws taken from the Carboniferous limestone which are unlike anything before found in our Carboniferous rocks. They include jaws of a new species of *Rhizodus* resembling *R. Hibberti* of the Lower Carboniferous rocks of Scotland, and jaws, teeth, and bones of another large Ganoid allied to *Rhizodus*, which I have called *Cœlosteus* from its hollow bones. These will be found described below.

[1] Acadian Geology, p. 253, *et seq.*

[2] Trans. Am. Philos. Soc., vol. 11, 1860, p. 87.

Order CROSSOPTERYGIDÆ.

CŒLOSTEUS, nov. gen.

Fishes of large size allied to *Dendrodus* and *Rhizodus*. Only a coracoid, mandible, and tooth have yet been found, but these certainly represent a fish generically different from any before met with on this continent. The bones are peculiar in their structure, consisting of a thin shell of dense osseous tissue, inclosing large cavities, once doubtless filled with cartilage. In this respect they resemble the bones of *Dendrodus* and contrast strongly with those of *Dinichthys* and the allied genera of Placoderms, *Titanichthys*, etc. In *Dinichthys* the coracoid is a bone nearly as large as one's arm and half as long, composed of dense bone-tissue throughout. The corresponding bone in *Cœlosteus* is about a foot in length and an inch and a half in diameter at the middle, and the central cavity is as large, relatively, as in the long bones of birds; the shell which surrounded it being but from one-eighth to one-quarter of an inch in thickness.

The dentary bone is about one foot in length, two and one-half inches wide in the middle, where it is one and a quarter inches in thickness, and four inches wide at the posterior end, where it was doubtless joined to the angular and articular elements. On the outside the posterior half is excavated to form a deep sulcus for the reception of the motor muscle, which must have been of unusual power. On the inside the jaw is flattened and gently arched downward to the rounded lower edge. The upper side bears on the outside a subacute toothless ridge; within and below this is a wide shoulder with seven broad and shallow pits, in which were planted the rounded bases of large, conical teeth This is a structure in some respects similar to that of the mandible of *Dendrodus*, but the jaw of *Cœlosteus* is much broader posteriorly, having a triangular outline like that of *Amia*, and has as its most striking feature the deep sulcus to which reference has been made above. The exterior surface of the jaws of *Dendrodus* is also strongly tuberculated, whereas in *Cœlosteus* it is smooth or coarsely striated longitudinally. The dentition, too, differs in a marked degree from that of *Dendrodus*, in which a row of closely set teeth of small size crown the upper and

outer margin of the jaw, and the great teeth planted in shallow sockets are in pairs, while in *Cœlosteus* the marginal ridge is without teeth and the great laniaries set along the interior shoulder are single and nearly equidistant.

The difference which the jaw before us exhibits from that of *Rhizodus* is still more strongly marked, though there is a similarity of plan in their construction. The teeth in *Rhizodus* form two rows, as in *Dendrodus*, and the large ones which compose the inner row are also sometimes in pairs. Dr. Traquair has shown[1] that the jaws of *Rhizodus* are segmented; a suture separating that part which bears the anterior laniary tooth from that which carries the second pair, and this from the others, etc.

The teeth of *Cœlosteus* are strong, conical, straight, acute and smooth above, plicated below; they have the complicated interior structure of the teeth of *Dendrodus*, but differ from these in being plicated only at the base. In the latter character they agree with the teeth of *Rhizodus*, but are apparently less compressed and straighter.

We have found as yet too little of the bony structure of *Cœlosteus* to warrant any positive statements in reference to its zoological affinities, and yet there are some points which have come under our observation which are quite remarkable, and such as suggest further examination when more material shall be obtained.

The hollowness of the bones has already been noticed as a striking feature in their structure, and it may also be said that the bone tissue presents a granulated appearance, which is much like that of the prismatic cartilage we sometimes find representing the outlines and in part the substance of the skull and jaws of certain fossil Elasmobranchs; *e. g.*, *Diplodus* in the Coal Measures, in which parts of the skeleton were partially ossified, though the tissue retained the granular structure of cartilage. The mode of attachment of the teeth in *Cœlosteus* is also peculiar and in some respects shark-like. In all the Elasmobranchs the bony and enameled teeth are attached to the jaws by ligaments and the jaw tissue is sometimes molded onto the base of the teeth, giving them greater firmness. A similar mode of attachment of the teeth obtained in *Dendrodus* and apparently in *Rhizodus*, but in

[1] Annals and Mag. Nat. Hist., April, 1877.

those genera the sockets were deeper and the teeth more firmly fixed in them.

In some respects, therefore, it will be seen that *Cœlosteus* is allied to the Sharks, and it is possible may be found to form a sort of connecting link between them and the Ganoids. Of this, however, better proof will be needed before it can be made the basis of any generalization. We find that the ossification of the skeleton varies considerably among the Elasmobranchs, and the most natural method of increasing the amount of bony tissue in the skeleton would be to ossify and indurate the external surface of the bones, thus giving them greater strength without adding greatly to their weight. Possibly we have in *Cœlosteus* an example of this stage of progress, and without venturing any premature conclusion as to its cause or history, I deem it proper to call attention to this particular structure, hoping that those who may come into possession of more and better material may find an explanation of what is now somewhat enigmatical.

Of known fossil fishes *Cœlosteus* perhaps comes nearer to *Pappichtys* Cope[1] than any other. Species of this genus have been described by Leidy, Marsh, and Cope. They occur in the Eocene rocks of the interior of the continent, and have been regarded as closely allied to, if not generically identical with, *Amia*. Should more material show *Cœlosteus* to be really allied to *Amia*, it would carry back the line of descent of this interesting Ganoid much farther than it has before been traced.

Cœlosteus ferox, n. sp.

Plate XXXV, Figs. 1–4.

The detailed descriptions of the few remains of this species yet found are given in the characters of the genus of which this is taken as the type. The specific name is chosen from the truly formidable character of the dentition. The dentary bone was very thick and strong, twelve to fifteen inches in length, and carried seven conical teeth, of which the largest were fully eight centimeters in length by fourteen millimeters in diameter at the middle and two centimeters at the base. Jaws bristling with such teeth and moved by the powerful muscles that are shown to have been attached

[1] Geol. Survey Territories, vol. 3, book 1, 1884, pl. 3, p. 56.

to them must have been capable of lacerating and destroying most of the inhabitants of the Carboniferous ocean. Sharks were the most abundant and the most powerful of the fishes in that sea, and to these *Cœlosteus* must have been a formidable antagonist.

It will be noticed that the jaw described above has lost all of its teeth and it has apparently suffered long maceration. The treatment to which it has been subjected may also have removed from it more than the large teeth, of which the sockets yet remain, viz, a tuberculated surface and a row of small teeth. Were these present it would come near to *Rhizodus*, but the jaw of a well-marked species of that genus recently discovered by Mr. McAdams in the same beds shows the exterior tuberculation, the row of small teeth along the upper margin, and the great laniary teeth still in position and deeply implanted in the massive dentary bone.

RHIZODUS ANCEPS, n. sp.

Plate XLIII, Fig. 1.

Dentary bone one foot or more in length, massive and strong; exterior surface coarsely pitted and tubercled; upper margin set with numerous, closely crowded, conical, acute, robust, striated teeth about half an inch in height, and with three or more laniary compressed, ancipital, enameled, polished fangs, plicated at the base, two inches or more in height, by nearly an inch in breadth. These laniary teeth rise from a shoulder or shelf which runs along the inner side of the mandible, and are deeply rooted in its substance The largest is set at or near the symphysis, where the mandible is tumid and very massive. This tooth is slightly curved, much compressed, with trenchant edges; the others are somewhat smaller, less compressed, and less curved.

Only about ten inches of the anterior extremity of the right mandible of this fish is yet known. It was obtained by Mr. William McAdams from the Saint Louis limestone at Alton, Ill. It is considerably mutilated, but shows two laniary teeth in position and the impression of a third. The second is located four and a half inches behind the first, the third three inches behind the second. As the jaw is seen from the outside the total length of the laniary teeth is not shown, but the anterior one probably projected three

inches or more above its base, where it was fully an inch in width, and it was deeply implanted in the dentary bone. The summit is rounded, evidently worn by use, but was probably once acute. It resembles closely the corresponding tooth of *Rhizodus Hibberti*, from the Carboniferous rocks of Scotland, but is more compressed, the margins being slightly excavated to render the edges thin and trenchant, so that the section is not perfectly lenticular, as is the case with the laniary teeth of the Scotch species.

The jaw before us shows nothing of the segmented condition which Dr. Traquair claims[1] is a marked character of *Rhizodus* and *Rhizodopsis*, but this feature would probably not be visible unless the jaw were seen from the inside. The general aspect of our specimen is such, however, that I cannot doubt it represents a species of *Rhizodus* and one very closely allied to that which is figured in most text-books on geology. It is also of special interest as affording the first positive evidence of the existence of this great sauroid fish in the waters of North America during the Carboniferous age. The scales and teeth from the Coal Measures, to which I have given the names of *R. quadratus*, *R. occidentalis*, *R. lancifer*, and *R angustus*, are only provisionally and doubtfully referred to this genus. We may be almost certain, indeed, that they should not be associated generically with the great Lower Carboniferous fish (*R. Hibberti*), which has been made the type of the genus. The specimen now under consideration is, however, so much like those from Scotland, that it is even a question whether it should be regarded as specifically distinct. If this specimen had been obtained from the British Islands probably no one would hesitate to identify it with *R. Hibberti*, but on comparing the great anterior laniary with a number of fine teeth which I have from Scotland, I find that it is more compressed than any of them, and is distinguished by the broad, shallow sulcus which borders the margin, making the slopes from the center to the edges concave. This is a device conspicuous in the spines of *Machæracanthus*, and one of which we make use in the construction of bayonets and some of our razors. Hence it has seemed to me best to consider it a new species.

In the description of *Cœlosteus ferox*, given on another page of this memoir, I have alluded to its affinities with *Rhizodus*, and I have hesitated

[1] Annals and Mag. Nat. Hist., April, 1877, p. 299.

somewhat in pronouncing the late discovery of Mr. McAdams distinct from the one which he formerly made in the same quarries at Alton. That is, I have thought it possible that the jaw of *Cœlosteus* might have belonged to the same fish, but it will be noticed that in *Cœlosteus* the pits which mark the positions of the great laniary teeth are almost equally spaced and are closely approximated; furthermore, in *Cœlosteus* there is no indication that the mandible was segmented; on the contrary, it was evidently solid throughout. In *Rhizodus*, on the other hand, the laniary teeth are irregularly spaced, few in number, and remote from each other; characters conspicuous in the jaw now described, but wanting in that to which the name *Cœlosteus* was given.

Again we have in *Cœlosteus* no indication of the pitting and tuberculation of the external surface so conspicuous in *Rhizodus*, and the anterior extremity of the dentary bone is not tumid. Hence, with the material now before me, I am led to believe that the jaws obtained by Mr. McAdams belong to two allied but distinct fishes.

It is probable that the discovery of these curious remains by Mr. McAdams will stimulate further and careful search for other traces of the great fishes they represent, and there is no doubt that material will be obtained sooner or later which will clear up all questions in regard to their structure and relations.

The Saint Louis limestone is exposed at a great number of localities in Indiana, Illinois, and Missouri; and at Greencastle, Alton, Saint Louis, and other places it has yielded a large number of fish remains, and it has therefore been already somewhat carefully exploited, but no trace of the great fishes now described, not even of any Ganoid, were obtained from it up to the time when Mr. McAdams discovered the jaw of *Cœlosteus.* We may therefore infer that these fishes were not numerous in the Carboniferous seas, and many years may elapse before we shall get a more complete record of their lives.

In the splendid collections of fish remains made from the Mountain limestone by Professor Worthen, Mr. Van Horne, Mr. St. John, and others, so fully illustrated in the reports of the Geological Survey of Illinois, it will be noticed that no traces of Ganoids appear, while the teeth and spines of

Sharks are so numerous as to show that Elasmobranch fishes were much more abundant in the Carboniferous sea than in those of the present or any other geologic age. The exception to the rule of the domination of the Sharks offered by the Ganoids discovered by Mr. McAdams is therefore of special interest, and we can see in the evidence furnished by their jaws and teeth that they were quite capable of contending successfully against any of their Elasmobranch antagonists; indeed, none of the Sharks yet known to us as inhabitants of the Carboniferous sea were provided with a dental armament as formidable as that of *Cœlosteus* or *Rhizodus.* The largest of the Carboniferous Elasmobranchs, *Archæobatis gigas, Orodus ramosus, Psammodus grandis*, and *P. plenus*, had crushing teeth, and doubtless lived upon mollusks, crustaceans, and crinoids, while the species with cutting and piercing teeth, *Petalodus* and *Cladodus*, were much less formidably armed than *Rhizodus.*

In the fish fauna of the Devonian age the great Crossopterygian scaled Ganoid *Onychodus* stood out in strong contrast to the number of large and small Placoderms with which it was associated, and it is interesting to note that in the Carboniferous sea another large and formidable Crossopterygian, *Rhizodus*, contrasts equally with the crowd of Elasmobranchs. We may even suspect that in each case the Ganoid was the most formidable, since with very powerful dental weapons he must have had a flexible scaled body that would allow of greater celerity, and while *Onychodus* would have been no match for *Dinichthys* if once within the grasp of its massive jaws, it could easily avoid them, and with its projecting intermandibular teeth two or three inches in length could have lacerated the exposed portions of the body quite at his leisure. So *Rhizodus*, with a gape of perhaps two feet, and jaws set with laniary teeth three or four inches in length, if he had the address to avoid the formidable dorsal and pectoral spines of the Sharks, would have found their shagreen-covered bodies easily penetrable.

Order ELASMOBRANCHII.

Genus PHYSONEMUS.

The genus *Physonemus* was named (though never described) by Prof. L. Agassiz in 1837,[1] but the spines to which the name was applied were well known, so it was recognized and a generic description given by McCoy.[2] He also described two species, one, that which had suggested the generic name to Agassiz (*Ph. subteres*), and a new one, which he called *Ph. arcuatus.* Another spine, named and described by Agassiz[3] as *Onchus hamatus*, having the strong curvature of *Physonemus*, has been referred to that genus by Mr. J. W. Davis.[4] He has also added another species to the list, (*Ph. attenuatus*,) which, though having the strongly recurved form of the type species of the genus, is too imperfectly preserved to admit of any positive assertion as to its generic relations. From the peculiar form of the base, indeed, it seems more probable that this is but one branch of the forked spine of *Cladacanthus*, Ag

In all that has been written by Europeans on the spines of *Physonemus* it has been supposed that they were set on the dorsal line, with a very strong backward curvature; but in a description of *Physonemus gigas*[5] I have called attention to the characters which indicate that this spine, as well as the one described by McCoy, was curved forward instead of being straight or curved backward, like most of the dorsal spines of Elasmobranch fishes; supposing the line of large, stellate tubercles set along the concave border, as well as the direction of the oblique line joining the plain and ornamented surfaces, to indicate that the curved border was anterior. These characters are shared by the spines upon which I have based the description of *Drepanacanthus*,[6] illustrated in the figures of *D. gemmatus.*[7] It is therefore not certain that these last-mentioned spines and *Physonemus arcuatus*, McCoy,[8] should not be united under the same generic name; but a comparison of specimens will alone suffice for deciding this question.

[1] Poissons Fossiles, etc., vol. 3, p. 176.
[2] Brit. Pal. Fossils, p. 638.
[3] Poissons Fossiles, etc., vol. 3, p. 9, pl. 1, figs. 7, 8.
[4] Mon. Fossil Fishes Carboniferous Limestone series Great Brit., p. 370.
[5] Geol. Survey Illinois, vol. 4, p. 373.
[6] Ibid., vol. 2, p. 120.
[7] Ibid., p. 123.
[8] Ibid., vol. 4, p. 373, pl. 2, fig. 17.

Another, and in some respects very different, kind of Elasmobranch spine, represented by several species, has been described by Mr. Orestes St. John under the name of *Physonemus*.[1] These are relatively broad and strong spines, sometimes ten or twelve inches long, the broadly conical summit alone being solid, the middle and lower portions of the convex border being opened by a deep furrow, on either side of which the margins thin to feather-edges; the sides and concave border are comparatively smooth and without ornamentation of any kind. About one-third of the length from the basal extremity the concave margin is raised and expanded to form a marked, sometimes swollen and overhanging shoulder, which in greater or less development is a conspicuous character in all the species. In the numerous and carefully drawn figures[2] the aspect and structure of this singular group of spines are well represented. It will be seen by reference to these figures and the accompanying descriptions that the exterior surface is represented as plain, and it is supposed by Mr. St. John that it was once covered with enameled tubercles, which have all been removed.

I have recently had an opportunity of examining about fifty spines collected by Dr. W. Clark from the Berea grit, the central member of the Waverly group (Lower Carboniferous), at Berea, Ohio, which throw new light upon the structure and position of this group of defenses. These spines apparently all belong to one species, which closely resembles *Physonemus Altonensis*,[3] St. J. & W., attaining about the same size, viz, from six to ten inches in length; the only marked difference between the spines obtained from Berea and those from Alton being that in the most complete Berea specimens the shoulder on the concave margin is much thicker and broader and is somewhat bilobed. All these specimens possess, however, some features which either are not present in those from the Carboniferous limestone of Illinois or have been overlooked by Mr. St. John, viz: (1) they are all unsymmetrical, the deep sulcus of the convex side is not central, one of its walls being thicker and broader than the other; (2) they are rights and lefts; in a large number it is easy to see that they may be somewhat equally divided into pairs. This means that they did not belong to the dorsal but to the paired fins, the pectorals or ventrals; it is impossible to assert posi-

[1] Geol. Survey Illinois, vol. 6, p. 448 *et seq.* [2] Ibid., vol. 6, pls. 18, 19. [3] Ibid., p. 454, pl. 19, figs. 1–3.

tively to which of these, but since we have several examples of pectoral spines among the ancient sharks (*Gyracanthus* and *Machæracanthus*) and innumerable examples among living fishes, while ventral spines are almost unknown, we may infer that they were pectoral spines.

All the specimens referred to were obtained by Dr. Clark from a pyritous layer resting upon the Berea grit, where they are often replaced by pyrite, and for the most part imperfectly preserved. One specimen, however, found in the fine argillaceous shale which overlies the Berea grit, gives the complete outline of the spine, and what is of special interest, the fin that was attached to it is represented by numerous well-preserved rays lying closely approximated in their natural positions. The spine, which here has its complete form, has evidently suffered no abrasion, as is proved by the preservation of the fin itself; and as it is without ornamentation, we are compelled to believe that it never bore any tubercles. The base shows the outline of what seems to be a spheroidal head that fitted into the socket of an articulation. The fin rays are apparently jointed towards the base, dividing above into thread lines, which must have been at least partially ossified, since many of them are continuous to their extremities, which form a curve that must be nearly the outline of the fin.

In the associated beds of the Waverly group, as well as in the Berea grit, a large number of dorsal spines have been found, among which are three species of *Ctenacanthus*, and with these in several instances rays, that probably belonged to the dorsal fins of which the spines formed the defenses. These fin rays are six to eight inches in length by a quarter of an inch in diameter at the base, tapering to an acute point; they are smooth and without articulation, but that they were at least partly osseous is proved by the perfection of their preservation.

At Vanceburgh, Ky., in a black shale of the Waverly group, among many other fish remains described in the Palæontology of Ohio, the tail of a large shark was found in which the fin rays of the lower lobe were distinctly preserved and had evidently been ossified. This specimen is now in the State Museum at Frankfort, Ky.

From the above description of the group of spines typified by *Physonemus Altonensis*, St. J. & W., it will be seen that they are so different from

the type species of *Physonemus* (*Ph arcuatus*, McCoy), that they should not be included in the same genus. I would therefore propose for the former a new generic name and briefly define it as follows:

STETHACANTHUS, nov. gen.

Pectoral spines of medium or large size, unsymmetrical (rights and lefts), broadly falcate in outline, the conical summit compressed, with anterior and posterior margins rounded. Below the solid summit the posterior margin is opened by a deep sulcus, of which the walls, of unequal thickness, terminate posteriorly in thin and fragile edges; anterior border gently concave, about one-third its length from the base rising into a strong, often tumid, shoulder; basal portion narrow and compressed, terminating in a cartilaginous condyle for articulation. In life the posterior sulcus was occupied by the base of the pectoral fin. Type species *St. Altonensis*, St. J. & W., sp.

For the species found at Berea, Ohio, I propose the name *Stethacanthus tumidus;* giving as its specific characters those of the genus with the following additions: Spine large, massive, laterally compressed, upper half triangular in outline, anterior shoulder broad, tumid, overhanging, and somewhat bilobed.

Since the above notes were written I have received from Alton, Ill., a number of specimens of *Stethacanthus Altonensis* which show the want of symmetry noticed in those from Berea. One of these specimens is of extraordinary size and of unusual breadth, so I have thought best to give figures of both sides of it in order to show with its dimensions the want of symmetry, one of the sides being as usual considerably shorter than the other.[1]

Labodus marginatus, n. sp.

Plate XIX, Fig. 9.

The little tooth represented by the figure cited above is one of several received from Greencastle, Ind., where they were obtained from the Saint Louis limestone. They evidently belong to a group of palate teeth of which many have been found in the Lower Carboniferous limestone at Armagh,

[1] See pl. XXIV, figs. 1, 2.

Ireland, and which were named by Agassiz, *Labodus*, *Copodus*, *Characodus*, etc. Similar teeth occur in the Chester and Saint Louis limestones in Illinois and Missouri, and some of these have been described by St. John and Worthen as species of *Copodus*. All of these consist of oval, rounded, or quadrangular dental plates of small size, arched form, and polished, pitted, enamel surface. Since there is no evidence of co-adaptation with other teeth at the sides, it has been thought that they formed a single series of three or more, which were placed in the central part of the mouth above and below and had the functions of the teeth of *Ætobatis*, *Myliobatis*, etc.

The teeth belonging to this group were named but never described by Agassiz. His work has been supplemented by Morris, McCoy, and J. W. Davis, who have endeavored to perpetuate Agassiz's names and classification. Without more material in our hands it would be presumptuous to attempt a review of the work of those who have endeavored to distribute these peculiar fish teeth into generic groups, as it is evident that the distinctions between Agassiz's genera are not strongly marked. It is impossible for us with certainty to refer the specimens we find to one or another of several genera, and if we may judge from the illustrations given by Mr. J. W. Davis in his Fossil Fishes of the Carboniferous Limestone, it would seem that some of these genera should be united. I am strengthened in this conclusion by an examination made some years ago, through the courtesy of Professor Agassiz, of the large collection of fish remains which he had brought to this country from Armagh. These were generally named by him, and of some of his species specimens are before me as I write. Among these is a fish tooth which bears the name of *Characodus*. This is so like the one now figured that I must think them generically identical; but the genus *Characodus*, Ag., as defined and illustrated by Mr. Davis, is considerably different, the teeth being much longer transversely and with salient cornua. If we are to consider Mr. Davis's descriptions and illustrations as an authoritative supplement to Agassiz's work, then the tooth now figured should rather be considered a species of *Labodus*. So, for want of good evidence to the contrary, I place it there provisionally, but record its differences from any other known species by giving it the name *marginatus;* the crown surface being bordered on three sides by a distinct marginal band.

PHYSONEMUS STELLATUS, n. sp.

Plate XXI, Fig. 12.

Spine relatively small, much compressed, broad at the base, rapidly narrowing to the summit, which is strongly recurved; posterior margin formed by extensions of the sides until they become extremely thin and widely separated by the continuous posterior furrow; sides above the unornamented base covered with lines of numerous, small, stellate, enameled tubercles, which on one side reach quite to the margin, on the other fade out about two-thirds of the distance from the anterior margin to the posterior furrow; thus showing a want of symmetry.

In general aspect this spine is somewhat like *Ph. arcuatus*, McCoy,[1] but is much broader and more compressed, and the ornamentation of the upper portion consists entirely of rows of distinctly separated stellate tubercles, rather than of pectinated ridges, as is the case with McCoy's species. The most striking features in the fossil before us are the compressed form and the great breadth of base, by which it may be at once distinguished from all other described species.

Formation and locality: Saint Louis limestone; Greencastle, Ind.

ORTHOPLEURODUS CARBONARIUS, N. & W., sp.

Plate XIX, Fig. 17.

I have received from Mr. Alexander Butters, of Carlinville, Ill., a complete posterior tooth of this species, which has seemed worthy of representation. It shows a beautifully punctate crown surface, having quite the form of those from which the original description was drawn, surrounded by a broad margin which was evidently overlapped by the integument. This specimen is comparatively thin, and the enamel crown has been indented probably in fossilization, proving that the base was soft, perhaps in part cartilaginous. The type specimens show only the crown, and are much thicker as well as larger. If to these were added broad, rough margins, such as are seen in the figure now given, we should have teeth two to three inches long and fully an inch in width at the widest part.

[1] Brit. Pal. Fossils, 1854, p. 638, pl. 31, fig. 29.

CTENACANTHUS LITTONI, n. sp.

Plate XXV, Fig. 3.

Spines twelve to fifteen inches in length by three centimeters in width at the base of the ornamentation; form nearly straight, with a slight backward curvature; laterally compressed; section elliptical; anterior margin rounded, posterior somewhat flattened; ornamented portion occupied by many relatively narrow, closely crowded, longitudinal ridges, of which those on the anterior margin are broadest; on these are closely set, prominent, transverse, vertically compressed, lenticular, enameled tubercles; unornamented base very long, extending four inches or more beyond the lowest point of the enameled surface, outline conical, pointed, surface smooth or finely striated longitudinally; sides flattened; posterior margin open to tip. Above the base the posterior opening is narrow and reaches to the middle of the spine.

Only fragments of this remarkable spine have yet been obtained. A complete base with a small portion of the enameled surface is shown in Fig. 3, and it will be seen that this base is of remarkable length and smoothness. The ornamentation is crowded, as regards both the costæ and the tubercles; both are contiguous, with no open space between them; the tubercles are transversely lenticular, much broader than high, smooth and polished. They are sufficiently prominent to give a rasp-like roughness to the surface.

The summit of the spine is yet unknown, and nothing can now be said in reference to the posterior armature.

Comparing this with other spines of the genus it will be seen to be quite distinct from any heretofore described. The form must have been unusually graceful, and the ornamentation is more elaborate than in any other species known to me. The tuberculation of the surface is different from the ordinary pectination formed by transverse, sheath-like ridges on the costæ, but consists of distinct, bead-like tubercles closely set along the ridges, and from their prominence and distinctness liable to be broken off, leaving a series of flattened spaces upon which they rested. This ornamentation is

considerably like that of *Ct. Harrisoni*,[1] St. J. & W., but is much more crowded and the form of the spine is narrower and straighter.

Formation and locality: Saint Louis limestone; Saint Louis, Mo. Collected by Prof. A. Litton, who has contributed many new things from this geologic horizon and locality, and to whom it is dedicated.

CTENACANTHUS CYLINDICUS, n. sp.

Plate XXVI, Fig. 1.

Spines straight or slightly curved, from eight to twelve inches in length, broadly arched or crescent-shaped below, nearly cylindrical from the middle upward; medullary cavity large, open posteriorly above the middle; posterior face traversed by a very strong arched ridge; line separating plain from ornamented surfaces very oblique; all exposed surface occupied with enameled ridges, which are coarsest along the anterior face, where they frequently fork; near the posterior margin they are finer and more continuous; the pectination, which is general, is almost entirely confined to the sides of the ridges, the summit of each ridge being nearly smooth, the sides strongly denticulated; near the posterior margin the narrower ridges are slightly knobbed or beaded, as in many other species.

The most striking peculiarities of this strongly marked spine is its elongated and cylindrical form, and the coarse, dichotomous ridges, smooth on the top and denticulated on the sides. The specimens I have are incomplete, and show no denticulation of the posterior surface. This was probably present, however, near the summit. Another specimen than that which has formed the basis of the above description indicates a shorter and straighter spine, in which the ornamentation, though of the same peculiar character, is more sparse and open, and I have suspected that this was a posterior dorsal spine. Numerous dermal tubercles which occur with these spines indicate that the shark which bore them was protected by a coarse shagreen of which the individual tubercles were ornamented with concentric lines.

Formation and locality: Keokuk shale; Casey County, Ky. Collected by Mr. William M. Linney.

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[1] Geol. Survey Illinois, vol. 7, 1883, p. 236, pl. 23, fig. 1.

Harpacanthus fimbriatus, Stock., sp.

Plate XXI, Figs. 11, 11[a].

I have recently received from Hon. William McAdams, of Alton, Ill., a small spine which is represented by the figure (11) now given. It was taken from the Saint Louis beds of the Lower Carboniferous limestone near Alton. It is imperfect, but as it is new to our fauna, and is apparently identical with a spine recently described from the Lower Carboniferous limestone of Scotland, I have considered it worthy of notice.

Two specimens only of the species have been known hitherto; they were both found at Gilmerton, near Edinburgh, Scotland. The first was described by Mr. Thomas Stock in a paper "On the Structure and Affinities of *Tristychius*,"[1] and was referred to that genus with the name *Tristychius fimbriatus.* The second specimen was found at the same locality three years later, and was made the subject of a paper on "*Harpacanthus,* a new genus of Carboniferous Selachian Spines," by Dr. R. H. Traquair, F. R. S.[2] From a study of the second specimen found, which was more complete than the first, Dr. Traquair showed that it could not be included in *Tristychius*, which has a compressed and striated shaft with two rows of denticles on the posterior margin, while the spine described by Mr. Stock has a smooth and polished surface, a circular section below, and a single row of relatively large denticles set along the posterior margin near the summit. He therefore made it the type of a new genus, which he called, from its curved outline, *Harpacanthus,* or sickle spine. The base is recurved and terminates in an expanded and club-shaped extremity; the entire length is about two inches.

Our specimen lacks both base and summit, and yet it reproduces the peculiarities of the central portion of the Scotch specimens so exactly, that I am compelled to regard it as specifically identical with them. Where fractured below our spine is cylindrical, has a smooth and polished surface, with a central cavity which reaches nearly to the summit. The upper portion seems to have been somewhat compressed and the sides excavated in a broad shallow furrow.

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[1] Annals and Magazine of Natural History (5) XII, pp. 177–190, pl. 7.
[2] Annals and Magazine of Natural History for December, 1886.

One marked feature in this and the Scotch specimens is a peculiar prominence or flattened knob on the posterior margin considerably below the teeth. In its circular section, its central pulp cavity, its smooth and polished surface, and single row of relatively large recurved denticles, this spine resembles *Compsacanthus lævis*, N., from the Coal Measures of Linton, Ohio,[1] and it is possible they should be included in the same genus.

To permit comparison between the American and Scotch specimens I give herewith (Pl. XXI, Fig. 11[a]) a copy of Dr. Traquair's drawing of the spine lately found in Scotland.

Sandalodus crassus, N. & W.

Plate XXI, Figs. 6–8.

In the Report of the Geological Survey of Illinois, vol. 4, p. 369, Pl. IV, Fig. 3, I described and figured a fish tooth received from Dr. A. Litton, of Saint Louis, to which the above name was given. This tooth was imperfect, lacking the narrow anterior extremity and the extreme posterior angle. I have recently received from Mr. William McAdams, of Alton, a number of perfect teeth of this species, which show that the figure referred to above is liable to convey a wrong idea of the complete form. For this reason I have thought it best to give herewith two figures of these teeth as found in their most perfect condition. One of these, represented in Fig. 7, shows the crown essentially perfect, and but for the information afforded by that shown in Fig. 6 it would be regarded as a perfect tooth. From this latter, however, we see that when absolutely perfect the crown carries a narrow beveled margin from the middle of the straight side down to the posterior angle, and it is there prolonged into a prominent acute point, one-quarter of an inch or more in length. In all others of the great number of specimens which I have seen this point is broken way, but many of them show, more or less plainly, the beveled border separated from the crown by a distinct line of demarkation. This margin was evidently covered by integument, and the point formed by the prolonged angle doubtless served to increase the firmness of the ligamentous attachment of the bony teeth to the cartilaginous jaw.

[1] Palæontology of Ohio, vol. 1, p. 332, pl. 40, fig. 5.

Mr. O. St. John[1] unites *Sandalodus crassus* with *S. spatulatus*, N. & W.,[2] but a large number of specimens of *S. crassus* which I have received from Alton, Saint Louis, and Greencastle, conform closely with the type now figured, and among them all I find none which correspond with that from which the description of *S. spatulatus* was taken. Mr. St. John considers that as simply a much-worn tooth, but the wear of these crushing teeth came only on higher portions of the crown. Of this a good illustration is given in the specimen represented in Fig. 8, a normal tooth of *S. crassus*, but having all the more elevated portion worn away by use. The margins are complete and the enameled surface intact and polished, except in the central part, which bore the brunt of the attrition to which the tooth was subjected. In this specimen we see nothing of the beveled border or the projecting point which shows so plainly in Fig. 6, but that is due to the fact that here the enameled crown is separated from the bony base.

Orodus ramosus, Ag.

Plate XXVII, Fig. 29.

Orodus multicarinatus ?, N. & W.; Geol. Survey Illinois, vol. 2, p. 62, pl. 4, fig. 13.

To the courtesy of Dr. Charles Rominger, former State geologist of Michigan, I am indebted for the beautiful tooth now figured It is represented of the natural size; is four and a half inches long by thirteen lines wide at the center; it shows the entire form of the crown and all the details of the surface markings. The general shape is similar to that of most of the large teeth of *Orodus;* i. e., it is broadest and highest near the middle, narrowing to either side, somewhat bent in outline. The crown is covered with a series of sharp, flexuous, and somewhat pectinated carinæ, of which the most conspicuous traverses the surface from end to end, but eccentrically. From this ridge (longitudinal as regards the tooth, transverse with reference to the mouth of the fish) descend to the margins at frequent intervals equally strong, sharp, simple, or forked pectinated branches These cover all the crown surface, but less closely on the subcentral cone, which is broad and prominent. The enameled surface is obscurely punctate throughout.

[1] Geol. Survey Illinois, vol. 7, p. 188. [2] Ibid., vol. 2, p. 103, pl. 10, fig. 2.

In size, form, and markings this tooth corresponds closely with some of the specimens of *Orodus ramosus*, Ag., of which species a good representation may be seen in the geological collection of the School of Mines, Columbia College, and there can be no reasonable doubt of their specific identity. It is probable also that the tooth described and figured in the Geological Survey of Illinois, volume 2, under the name of *Orodus multicarinatus*, will prove to belong to the same species. This specimen is only a fragment, a part of the central cone of a tooth which must have been twice as large as that now figured, or any tooth of *O. ramosus* before known, and the surface bears a larger number of carinæ than have been seen on the central part of the crown of a tooth of that species; but these differences are rather of degree than of kind. The peculiar ornamentation of the species is repeated, and we can say without hesitation that if not the same it is closely allied to that of the Old World. All the specimens referred to are found at about the same geological level; that figured in the Illinois report was from the Goniatite limestone, the base of the Lower Carboniferous at Rockford, Ind. The foreign specimens came from the Mountain limestone, and that now under examination from the Waverly sandstone at Grindstone City, Mich.

Mr. J. W. Davis has recently published in his paper, "The Fossil Fishes of the Carboniferous Limestone,"[1] better illustrations of the teeth of *Orodus ramosus* than any before given, and has shown that they exhibit as great differences among themselves as they do from the teeth with which I have compared them.

ACONDYLACANTHUS OCCIDENTALIS, N. & W.

Plate XXV, Fig. 6.

The spines to which this name has been given are from the Saint Louis limestone. They are from eight to twelve inches in length, relatively slender, gently arched backward; sides flat or arched; anterior edge sharp; posterior edge deeply furrowed, and bordered by two rows of small, acute, compressed and depressed hooks. The lateral surfaces are occupied by numerous subequal, parallel, continuous, smooth, flattened costæ; near the base about fifteen, in the middle twelve, and within an inch of the summit

[1] Trans. Dublin Royal Society, 2d series, vol. 1, p. 391, pl. 50.

eight; the number being increased below through bifurcation. The summit is acute, the unornamented base very short and abruptly pointed; the denticles extend from the summit two-thirds of the entire length.

From Mr. William McAdams, of Alton, Ill., and Mr. H. A. Wheeler, instructor in Washington University, Saint Louis, I have recently obtained much better specimens of this spine than I had when I described the species in the Illinois report.[1] These show the summit and base, both of which were before unknown; the former is acute, the latter abruptly contracted, the unornamented portion remarkably short. In a spine of eight inches in length the costæ reach within five-eighths of an inch of the end on the anterior border and within about an inch behind.

To the description of this species in the Illinois report I added the following remarks:

> We have referred these spines to *Leptacanthus* with much doubt, as there seems to be little probability that they are generically identical with those from the Oolite, which Agassiz first designated by that name. It is true the general form is similar, but the striated or confusedly costate surface of the typical *Leptacanthi* must have given them an aspect widely different from that of these spines, so uniformly and regularly ribbed throughout. The suspicion that these differences are generic is also strengthened by the fact that up to the present time no teeth have been found, either in the Lower Carboniferous or Jurassic rocks, which have been referred to the same genus; and it is scarcely probable that, while the fin rays of these ancient Placoids have been met with in considerable numbers, the much more numerous teeth could have been overlooked. We infer, however, from the figures and descriptions of Professor McCoy (British Palæozoic Fossils, p. 633, Pl. 3g, Figs. 13, 14 and 16), that the spines which he calls *Leptacanthus junceus* and *L. Jenkinsoni* are generically identical with ours; the latter species being distinguishable from that before us only by the less perfect regularity of costation near the base, greater spacing of the denticles, and the striation of the surface—fair specific differences. If, then, Professor McCoy's Carboniferous fin spines are properly referred to *Leptacanthus* ours should be so; but for the reasons given above it seems in some degree probable that the reference of his specimens to that genus was unwarranted. The resemblance which the spines before us and those of Professor McCoy bear to some of the more slender and compressed forms now included in *Ctenacanthus*, such as *Ct. distans*, McCoy, and *Ct. gracillimus*, N. & W., is very marked, and is suggestive of closer relationship than has been assigned them. These species of *Ctenacanthus* have been associated with the great hybodoid spines *Ct. major*, Ag., *Ct. hybodoides*, Egerton, etc., simply on account of their sharing with them the inconstant character of the tuberculation or pectination of the longitudinal costæ. As we have before remarked, this is almost too variable and superficial a character to serve as a bond of generic union between organs of which

[1] Geol. Survey Illinois, vol. 2, p. 116.

the facies are so diverse. We should therefore suggest to those who, hereafter in possession of more ample material, may be better able to adjust the classification of these fossil fishes, the question whether the long, slender, and flattened species of *Ctenacanthus*, cited above, should not be united with *Leptacanthus junceus*, *L. Jenkinsoni*, and the present species in a generic group, distinct from both *Ctenacanthus* and *Leptacanthus*.

Messrs. St. John and Worthen,[1] acting upon the above suggestion, though without reference to it, make this species and two others described by themselves—one from the Kinderhook of Burlington, Iowa, and the other from the Keokuk of Warsaw, Ill.—the types of a new genus, to which they give the name of *Acondylacanthus*.

Up to the present time we remain in ignorance of the teeth that were associated with these spines. They will probably sometime be found to be such as are known by the names of *Cladodus* or *Orodus;* both of which have been seen associated with the spines of *Ctenacanthus*. The spines of *Acondylacanthus* have a general resemblance to those of *Ctenacanthus*, but are more slender than most species of that genus, and may be distinguished from them by the absence of all tuberculation on the parallel and relatively uniform costæ of the enameled surface. The base is also shorter than in any spines of *Ctenacanthus* which have come under my observation, though in this character they resemble some spines of *Asteroptychius*.

So far as yet known the spines of *Acondylacanthus occidentalis* are confined to the Saint Louis beds of the Mountain limestone.

ANTLIODUS ARCUATUS, n. sp.

Plate XIX, Figs. 3, 4.

Teeth about one inch in breadth by eight lines in height; outline elliptical; posterior face polished, gently concave laterally, more strongly vertically; upper margin subacute, lower margin bordered by about five relatively broad and strong enamel folds, which cover the lower third of this surface; anterior face equally divided between the crown and surface of attachment; crown portion strongly arched and highly polished, its inferior margin somewhat bow-shaped, and traversed by a single deep and broad furrow; adherent surface arched laterally, flattened vertically; root low,

[1] Geol. Survey Illinois, vol. 6, p. 432.

tumid, irregular, projecting but slightly below the arched margin of the anterior face.

These teeth have somewhat the aspect of those of *A. cucullus*,[1] N. & W., when seen from the posterior side, but they are less high, the band of enamel folds at the base is much broader, and they are more numerous; while the anterior face, with its upper half strongly arched and its single deep sulcus, proves it quite distinct.

Among the species described in the report cited below, *A. robustus* and *A. similis* (Pl. II, Figs. 9, 10) are much like this, but neither has the characteristic dorsal sulcus of the present species. The differences noticeable are also increased in significance by the fact that all the species compared come from different beds of the Carboniferous limestone, as *A. robustus* from the Chester beds, *A. similis* from the Keokuk, while the species now described is from the Saint Louis limestone at Spencer, Owen County, Ind.

POLYRHIZODUS LITTONI, N. & W.

Plate XIX, Figs. 5–6[a].

A short description and a single view of a tooth belonging to the above species have been published.[2] I have received from the Saint Louis limestone at Greencastle, Ind., teeth of the same species which show an interesting variation of form from that which was taken as the type. One of these has been figured to show this difference. The root, it will be seen, is much longer in proportion to the crown, and the concave surface occupies not much more than half of the posterior face. These differences may be individual, but more likely are dependent upon different positions in the mouth of the fish. Living sharks and the few fossil ones of which anything like a complete dental series has been obtained show considerable diversity of both size and form among the teeth which occupied central and lateral positions in the mouth, and frequently a marked difference between those of the upper and lower jaws. Hence there is danger that among fossil teeth which were scattered broadcast over the sea bottom such differences will

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[1] Geol. Survey Illinois, vol. 2, p. 41, pl. 3, fig. 1.

[2] Ibid., vol. 4, p. 357, pl. 4, figs. 10, 10[a].

be made the ground of specific distinction. It is desirable, therefore, that the range of variation in each species should be determined as accurately as possible.

PSAMMODUS GLYPTUS, St. J. & W.

Plate XIX, Figs. 7, 8.

Among a large number of fish teeth obtained from the Saint Louis limestone at Greencastle, Ind., are several teeth of *Psammodus*, which I have referred with some hesitation to the above species. They are oblong and quadrangular in outline, are unusually thin, and the crown surface is marked by a series of undulations which give them an aspect quite different from that of any other teeth of *Psammodus* I have before seen. Of known species of the genus those described and figured by St. John and Worthen[1] are like these in being thin and undulate, but the peculiar roughening of the surface which they describe is scarcely apparent; and yet much more material would be needed to justify the establishment of a new species upon this difference.

SECTION F.—FISHES OF THE COAL MEASURES.

The limestones and shales associated with the beds of coal and especially the cannel coals, have furnished in North America, as in Europe, a large number of fossil fishes. Most of these are small tile-scaled Ganoids allied to *Palæoniscus*, but with them a considerable number of much larger fishes of the same order have been found, such as *Rhizodus* and *Megalichthys*, and those belonging to the interesting family of the *Cœlacanths*. We also find here some *Dipnoans* (*Ctenodus*), but fewer relatively than in the rocks of the same age in the Old World; also a considerable number of Elasmobranchs, which are represented by spines, as *Ctenacanthus*, *Edestus*, *Orthacanthus*, etc., and by teeth, as *Cladodus*, *Diplodus*, *Petalodus*, etc.

Most of the Coal Measure fishes were apparently the inhabitants of fresh water. They include both Ganoids and Elasmobranchs which were among the largest and most powerful fishes known, such as *Edestus*, *Ctenacanthus*, *Megalichthys*, and *Rhizodus*. In the limestones of the Coal Measures,

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[1] Geol. Survey Illinois, vol. 7, p. 209, pl. 14, figs. 5, 6.

however, are some fish remains which we must consider marine, as those of the Crinoidal limestone of Ohio and western Pennsylvania, and the much thicker and more wide-spread limestones of Coal Measure age in the Far West. Here we find *Petalodus*, *Cladodus*, *Ctenoptychius*, etc., and in Arizona the only Palæozoic Pycnodonts yet found on this continent.

There are a few localities which deserve mention from the number of species they have furnished. These are Linton, Ohio; Morris, Belleville, and Carlinville, Ill. Probably there are many others quite as rich, but they have not yet been discovered or properly exploited.

The Linton locality is especially interesting and instructive. It has already yielded more than twenty species of fishes and nearly forty species of aquatic amphibians, all inhabitants of the same body of water. These are found in a thin stratum of cannel, which, over a limited area, underlies a thick bed of cubical coal (No. 6, of the Ohio Reports), of which the place is near the top of the Lower Coal Measures. This is a bed of coal which extends over some thousands of square miles, and it is usually a soft coking coal, not unlike that of the Pittsburgh seam, which lies about five hundred feet higher. At Linton, however, we have evidence that the great marsh in which the peat accumulated that formed Coal No. 6 was for a time a lake or lagoon, inhabited by the fishes and amphibians to which I have referred. While this remained an open body of water carbonaceous mud accumulated at its bottom, derived from the drainage of the neighboring marsh, which carried with it fine particles of completely macerated vegetable tissue. In this carbonaceous mud, now cannel coal, were buried the scales, bones, spines, and often entire individuals of the inhabitants of the water above. Sometimes nearly the whole mass is made up of animal débris. Many of the fishes and amphibians were highly carnivorous and powerful, as we learn from their teeth and coprolites. The largest of the amphibians must have been eight or ten feet in length, having strong jaws, set with numerous lancet-shaped teeth an inch or more in length. The largest fishes were probably not much their inferiors in size.

After a sufficient time had elapsed for many generations of fishes and aquatic salamanders to live and die the lake was filled by the extension of its peaty shores into it—just as so many lakelets are filled and obliterated

at the present time—and afterward over the cannel was formed a mass of peat, which has now become a stratum of cubical coal seven feet in thickness.

In the Linton cannel are buried fragments or entire individuals of all the inhabitants of this body of water which had hard parts—bones, scales, spines, or teeth—capable of preservation. Hence we here get a locally complete picture of the life of the Carboniferous age, and we find it to be unexpectedly rich and varied. In that age fishes and amphibians were the highest forms of animal life, and the amphibians were comparatively new-comers on the earth's surface. Yet they had multiplied and differentiated until this little pool contained millions of them, varying in length from six inches to ten feet and curiously diversified in their forms, their scales and spines and in the ornamentation of their enamel-covered heads.[1]

The following is a list of the fishes which have been up to the present time found at Linton. They are described in the Palæontology of Ohio:

Cœlacanthus robustus, Newb.
elegans, Newb.
ornatus, Newb.
Palæoniscus (*Elonichthys*) *peltigerus*, Newb.
Eurylepis tuberculatus, Newb.
corrugatus, Newb.
ovoideus, Newb.
insculptus, Newb.
ornatissimus, Newb.
granulatus, Newb.
minimus, Newb.
striolatus, Newb.
lineatus, Newb.
macrops, Newb.
Rhizodus angustus (teeth), Newb.
lancifer (teeth), Newb.
quadratus (scales), Newb.
occidentalis (scales), Newb.
Orthacanthus arcuatus, Newb.
gracilis, Newb.
Compsacanthus levis, Newb.
Diplodus compressus, Newb.
latus, Newb.
gracilis, Newb.
Ctenodus serratus, Newb.
reticulatus, Newb.
Ohioensis, Cope.

The most striking feature in this group is formed by the species of *Eurylepis*. These were beautiful little Palæoniscoid fishes, clothed in polished armor of smooth or ornamented scales, of which those on the sides are much higher than long; the head bones are also highly ornamented with tubercles, granulations, or thread-lines. They vary in length from one to five inches, and, coated as they frequently are with a brilliant film of pyrites, they appear as though wrought in gold upon a jet-black ground; the most beautiful of all fossil fishes.

[1] These amphibians all belong to Owen's group of the *Ganocephala*, so named from the enameled plates by which their heads were covered. Their bodies were generally protected by scales or spines of various kinds. In these characters as well as in size they surpassed the amphibians of the present day—frogs, toads, and salamanders—which are all small, and are clothed in a soft and naked skin.

The several species which have been enumerated differ from each other in size, the relative height and length of scales, or the ornamentation of the head bones. Probably some of these differences are dependent upon sex, age, or accidental variation within specific limits, but the great diversity in the altitude of the side scales—from double to five times the length—and the linear or tuberculated ornamentation of the cranium seem to prove that there were at least half a dozen distinct species. Although so numerous in this locality that many hundred individuals have been collected, no representative of the genus has been found elsewhere except a single specimen which I detected in the collection of Mr. J. C. Carr, of Morris, Ill.

The next most abundant fish at Linton is *Cœlacanthus elegans;* yet while perhaps a thousand specimens more or less perfect have been taken from one coal mine there, with the exception of a single one found at Morris no representative of this world-wide genus has been elsewhere seen in America.

The *Elonichthys* (*E. peltigerus*, N.) which appears in the list recurs in the cannel coal at Canfield, Ohio, and at Morris, Ill.

Perhaps the most interesting element in the Linton fauna is *Cœlacanthus elegans*, N. This is so much like *C. lepturus* of the English Coal Measures, that I have been doubtful whether it should be regarded as distinct; the only observed difference being the greater continuity and parallelism of the thread-lines which ornament the scales, jaws, and jugular plates of the Linton fishes. They are at least so much alike as to show that they have been derived from a common ancestry, and that the inhabitants of the widely separated localities where they are found came by migration from a common place of origin.

The similarity, not to say identity, of structure in this highly specialized group of fishes is a striking illustration of the tenacity with which organic forms hold to their characters through long periods of time and in diversified surroundings. The migration of these fishes must have been through bodies of fresh water, necessarily very slow and through great changes of environment, yet their very complicated structure, in both essentials and ornamentation, has been entirely unaffected by time—which would favor spontaneous or inherent variation—and circumstance, usually supposed to have almost unlimited modifying power.

The largest fishes of the Linton group are as yet known only by fragments, and we have therefore very much to learn about them The tessellated cranium of *Ctenodus* has, however, been found nearly entire. This is a foot or more in length, showing that the fish to which it belonged was of considerable size; but the few teeth of the genus yet found in this locality are disproportionately small.

The teeth of *Diplodus* are exceedingly common and some of them are of large size. In the largest (*D. latus*) the lateral denticles are broader, thinner, and more lancet-shaped than in any of those found in Europe.[1]

The two smaller species, which I have called *D. compressus* and *D. gracilis*, are hardly to be distinguished from those named by Agassiz *D. gibbosus;* but the spines of *Orthacanthus* found at Linton—which belonged to the same fishes—form two or three species, which are apparently all distinct from those associated with the teeth of *Diplodus* in foreign localities. In several instances I have found the cartilaginous jaws more or less perfectly preserved and still bearing the teeth; these formed many rows from front to rear, with many teeth in a row, lying appressed like the rear teeth of *Carcharias*, etc.

Taking all things into consideration, the Linton locality is the most instructive of all our known repositories of fossil fishes, chiefly because we have here the history of a colony which can be read with a good degree of completeness; a kind of window, through which we can look into the Carboniferous age, and over a limited area see everything that was taking place; and yet this was but a part, and a very small part, of a great whole. There is no doubt that the species found here once lived in a thousand other localities, and with them were many others of which we as yet have no traces.

The nodules of iron ore contained in the coal shales on the banks of Mazon Creek near Morris, Ill., generally contain organic nuclei, and thousands of beautiful specimens have been obtained there. They are usually fragments of fern fronds, but are sometimes shells, crustaceans, myriapods,

[1] All the specimens of this species found before my description was published (Palæontology of Ohio, vol. 2, p. 44, pl. 58, fig. 1) were without a central denticle, and I gave that as one of its characters; but Mr. M. C. Read has recently sent to me a large and finely preserved tooth, in which the middle cone, though very small, is distinctively visible.

scorpions, spiders, cockroaches, or fishes. Among the latter are three species of *Palæoniscus*, one of *Amblypterus*, and two of *Platysomus*, which are described in the Palæontology of Illinois. Large ornamented scales of two or three kinds are also occasionally met with in the iron-ore nodules; they have been referred to *Rhizodus*, but it is not at all certain that they belong to that genus. Since the notice of the Mazon Creek fishes was published in the report of the Illinois Geological Survey I have received from there a single specimen each of *Eurylepis* and *Cœlacanthus*, probably not distinct from those found at Linton.

In the shales of the Coal Measures at Belleville and Carlinville, Ill., Mr. Alexander Butters has collected a large number of fish remains; these consist mainly of the teeth of *Cladodus*, *Petalodus*, *Sandalodus*, *Orthopleurodus*, and the spines of *Edestus*. The latter all belong to the species *E. Heinrichsi*, N. & W., and are often disarticulated in such a manner as to show distinctly the structure and mode of growth of this singular organ. These I have illustrated with figures in another part of this memoir, and I will only say here that in this species, as well as in *E. minor*, which I have from the Coal Measures of Indiana, growth took place by additions of sheaths to the upper extremity of the first segment. This proves that the spine was all buried in the integument except the great compressed, enameled, crenulated denticles; each of which was borne at the extremity of its own segment or sheath. The spine is symmetrical, and therefore was placed on the median line, probably near the tail, where considerable freedom of motion would permit its being used to lacerate any attacking foe. I have suggested that it was carried far back on the dorsal line like the spines of *Trygon*.

I have included *Megalichthys* in the list of American Coal Measure fishes, because I have found in Ohio masses of scales and bones which are scarcely distinguishable from those of *Megalichthys Hibberti*, Ag These are rhomboidal in outline, half an inch to an inch in length; the surface covered with brown, highly polished, punctate enamel. They occur in a black shale over a bed of coal at Mineral Point, Stark County, Ohio, in circumstances similar to those in which the remains of *Megalichthys* are found in England.

Sir William Dawson has described in his Acadian Geology a number of Carboniferous fishes, of which those of the Albert mine and Horton Bluff have been already noticed; most of the others are from the Coal Measures.[1] New species of *Ctenoptychius*, *Diplodus*, *Rhizodus*, *Conchodus*, *Psammodus*, and *Gyracanthus* are described. Of these, *Conchodus* is apparently the palate tooth of a Dipterine Ganoid, probably belonging to the genus *Ctenodus*, and the *Gyracanthus* (*G. duplicatus*, Daw.) is one of the most peculiar and interesting species of the genus.

In addition to the literature of the Carboniferous fishes already cited I would refer the reader to the following papers:

Descriptions of the Remains of Fishes from the Carboniferous Limestone of Illinois and Missouri; by Joseph Leidy, M. D., Trans. Am. Philos. Soc., vol. 11, p. 87.

Descriptions of some Remains of Fishes from the Carboniferous and Devonian Formations of the United States; by Joseph Leidy, M. D., Jour. Acad. Nat. Sci. Phila., 2d series, vol. 3, 1855–1858, p. 159, Pls. XV, XVI, XVII.

In the Second Biennial Report on the Geology of Alabama, 1858, p. 38, Prof. M. Tuomey notices the occurrence of spines and teeth of fishes in the Lower Carboniferous limestone of that State. He mentions teeth of *Psammodus* and a spine of *Ctenacanthus* "closely allied to *Ct. tenuistriatus*, Ag," and gives rough wood-cuts of this and two species of *Cladodus*, which he names *C. Newmani* and *C. magnificus*. The former of these is too imperfect for identification, but the latter I have often recognized among the fish teeth obtained from the Lower Carboniferous limestone of Illinois and Indiana; very large teeth, with a central cone one and a half inches long and relatively small lateral denticles.

The fishes of the American Coal Measures have been so fully illustrated in the geological reports of Illinois and Ohio that it seems unnecessary to attempt a thorough review of them here, but notes on a few new or more remarkable forms will be found on the following pages.

[1] They are referred to in Acadian Geology, 1868, p. 209.

THE STRUCTURE AND RELATIONS OF EDESTUS.

The first of the remarkable group of fossils now included in the genus *Edestus* was brought to the notice of scientists by Dr. Joseph Leidy, in his description of *Edestus vorax*.[1] The type specimen was only a fragment of an organ that must have had a length of a foot or more by four inches in width and one and a half inches in thickness. The portion figured by Professor Leidy seems to have come from about the middle, and consists of a mass of bone composed of a series of segments, each of which carries at its upper margin an enameled, compressed, triangular, crenulated denticle one and a half inches in height and breadth. In general aspect these denticles considerably resemble the crenulated teeth of *Carcharodon*, but show this marked difference, that like all the cutting teeth of sharks these latter are flattened on one side, arched on the other, and terminate below in a bony base that had only a ligamentous attachment to a cartilaginous jaw; hence in death and decomposition the teeth were generally separated and scattered. In *Edestus*, however, the denticles are firmly anchylosed to a bony support.

At the meeting of the American Association held in Providence in 1855 another and quite different species of *Edestus* was exhibited by Prof. Edward Hitchcock. It was considered by him to be "the jaw of a shark, but of very peculiar character." Prof. Louis Agassiz, who was present, examined the specimen, and gave it as his opinion that it formed a part of the jaw of a shark allied to the sawfish. He stated that "the sword of *Pristis* is orginally composed of two bones, and if these should continue separated, each part, with teeth only on one side, would not be much unlike the fossil." He suggested that the fish had a corresponding jaw projecting from the opposite side of its head, and that both formed a powerful weapon of offense. He regarded it as belonging not only to an undescribed genus, but to a new family of fishes.

This specimen was obtained by the Rev. John Hawks in Park County, Ind., "in a layer of shale overlying a coal seam." Subsequently it was submitted by Dr. Hitchcock to Prof. Richard Owen, of London, who dis-

[1] Jour. Acad. Nat. Sci. Phila., 2d series, vol. 3, 1856, p. 159, pl. 15.

cusses its relations and gives a bad figure of it.[1] Professor Owen decided that it was not a jaw, but a defensive spine.

In 1863 I described[2] what proved subsequently to be a fragment of a spine similar to that exhibited at Providence by Professor Hitchcock, giving to it the name of *Edestus minor.* A figure taken from a photograph of a nearly complete specimen of this species was published in the report of the Geological Survey of Illinois, volume 4, Pl. I, Fig. 2, though wrongly named on the opposite page of explanations *Edestus vorax.* In the same volume, page 350, was published a description of a third species of *Edestus*, *E. Heinrichsi*, and a half-size figure is given on the plate cited above. To these three species I now add a fourth, of gigantic size, which I have named *Edestus giganteus*, and give in this memoir a description and a plate of it.

The geographical distribution of these species of *Edestus* is somewhat peculiar. The first specimen described (*E. vorax*) was obtained from the Coal Measures of Arkansas; the second (*E. minor*) from Park County, Ind.; the third (*E. Heinrichsi*) from shale over coal at Belleville, Ill., and the specimens of which a description and a figure are now published is from the coal shale at Decatur, in the same State. I should also say that I have other specimens of *E. Heinrichsi* from Vermillion County, Ind., and Carlinville, Ill., and of *E. minor* from Posey County, Ind. Thus it will be seen that all the specimens known, now quite numerous, are from the Mississippi coal field; that is, the coal area of Illinois and Missouri, once continuous, but now separated by the erosion of the immediate valley of the Mississippi.

In Ohio and Pennsylvania much more extensive excavations in the coal rocks and numerous collections of Carboniferous fossils have been made, but not a trace of *Edestus* has been found there. Hence we must infer that it never passed the highlands of the Cincinnati arch, which separated the western from the eastern coal basins.

The material in which the spines of *Edestus* are found is almost without exception the bituminous shale which occurs so often interstratified with the other elements of the Coal Measures, and very frequently resting upon coal.

From the black shale which forms the roof of a coal mine at Belleville, Ill., Mr. Alexander Butters, the superintendent of this mine, has taken hun-

[1] Palæontology, 2d edition, p. 124. [2] Geol. Survey Illinois, vol. 2, p. 84.

dreds of the segments which once composed the spines of *E. Heinrichsi.* This shale is apparently a fresh-water sediment, carbonaceous mud which accumulated in the lagoons of water that occupied portions of the coal marshes; either following a subsidence and then covering the coal, or synchronous with the peat from which the cubical coal is derived. In the latter case the amount of earthy matter associated with the carbon is less, and we then have cannel coal. Some of these lagoons must have been very large, and may perhaps have communicated with the ocean; for the fishes which bore these defensive and offensive weapons were of enormous size, and could not have been restricted to very narrow quarters, since they required a vast amount of food for their subsistence. The associated fossils include a large number of fish teeth, some of which belong to carnivorous sharks, as *Cladodus* and *Petalodus*, and others with crushing teeth, as *Orodus*, *Orthopleurodus*, etc. The habitat of *Edestus* would therefore seem to have been somewhat similar to that of *Rhizodus* and *Megalichthys*, of which the teeth, scales, etc., are so common in the coal shales and cannels of England and Scotland.

Prof. Henry Woodward describes[1] and figures a fossil from the Carboniferous rocks of Australia, to which he gives the name of *Edestus Davisi.* It is the impression of a bony arch about four inches long, on the convex border of which are set fourteen acute, compressed, lancet-shaped, crenulated denticles. It is more curved than the other described species of *Edestus*, but is so like them that Dr. Woodward seems to have been fully justified in placing it in that genus. In his discussion of the structure and relations of this fossil Dr. Woodward compares it with the segmented spines of *Pelecopterus*, Cope, from the Cretaceous rocks of Kansas, and is thereby led to consider it a pectoral defensive spine. There are, however, some points in the structure of this and other spines of *Edestus* which will be alluded to farther on, that make it difficult for us to accept this conclusion.

In August, 1887, Miss Fanny R. M. Hitchcock, an earnest and accomplished student of comparative anatomy, read a paper before the Biological Section of the American Association "On the Homologies of the so-called Spines of *Edestus*," in which she suggested that *Edestus* was an intermandibular arch of bone carrying teeth, and most like the dentigerous arch which

[1] Geol. Magazine, London, vol. 22 (1886), p. 2.

was held between the extremities of the mandibles in the great Crossopterygian Ganoid, *Onychodus sigmoides*, found in the Corniferous limestone of Ohio, and described[1] by me. There are perhaps no facts which disprove this hypothesis, and it is worthy of respectful consideration, but I would suggest that *Onychodus* was very widely separated zoologically from *Edestus*, which must have been a Plagiostome. At least, unless the skeletons of huge fishes like *Edestus giganteus* were cartilaginous, we should find their bones in the rocks where their spines are so numerous.

The structure and probable functions of *Edestus* have been discussed[2] by me at some length in the notes on *E. Heinrichsi*, and the conclusion is there reached that it is not a jaw, but the defensive dorsal spine of a Plagiostome fish. The considerations which led me to this conclusion are briefly as follows:

First. Although the denticles which crown the convex border of *Edestus* have the general form and crenulation of the teeth of *Carcharodon* and *Hemipristis*, their structure is in many respects quite different, viz: the teeth of none of the sharks are symmetrical; one face is flattened and the other is more or less arched; while the denticles of *Edestus* are equally arched on both sides.

Second. The teeth of sharks, while having enameled crowns, have tumid bony bases, attached by ligament to the cartilaginous jaws and separating readily from them; hence they are rarely found in place in the fossil state. The denticles of *Edestus*, on the contrary, are firmly attached to the bony arch from which they rise.

Third. The form of these fossils is quite unlike that of any jaw of fish, reptile, or mammal known; being roughly rounded at the base, the opposite extremity flattened, and bordered on one side by a sharp edge; on the other by crenulated denticles, one of which is terminal.

Fourth. The rounded, roughened base proves that this organ could not have been articulated with any bones and scarcely with cartilages, else we should have some evidence of co-adaptation. In this respect it resembles most of the dorsal spines of sharks and skates, which are implanted in the

[1] Palæontology of Ohio, vol. 1, p. 299, pl. 26, figs. 1-5; pl. 27, figs. 1, 2.
[2] Geology of Illinois, vol. 4, p. 350.

integument of the back and have a roughened base and bony structure, with various forms of enameled denticles on the margin.

Fifth. If the spines of *Edestus* were attached to the head as modified jaws and the homologues of the rostrum of *Pristis*, the base would present some evidence of anchylosis with the bones or cartilages of the head; whereas it is rounded, as though it had been buried in soft tissue. Again, the rostrum of *Pristis* is only partially ossified, while the spines of *Edestus* are composed of dense bone; and, further, the denticles of the rostrum in *Pristis* are set in alveolar cavities, from which they escape and are scattered about in the decay of the animal. We often find these denticles in the Cretaceous marls, but almost always isolated, like the sharks' teeth which occur with them. On the contrary, the denticles of *Edestus* are inseparably united with their bony bases, and they are perfectly preserved together.

Finally, if each spine of *Edestus* was one of a pair attached to the snout, like the rostrum of *Pristis*, *Xiphias*, or *Cœlorhynchus*, they must have been entirely separated, for they bear no marks of contact, and they would certainly have been unsymmetric l. We are therefore driven by the bilateral symmetry of *Edestus* to conclude that it was not one of a pair, but that it stood alone somewhere on the median line, either as a homologue of the intermandibular arch of *Onychodus*, the dorsal spines of *Chim ra* and *Hybodus*, or of the caudal spines of *Trygon*.

The suggestion of Miss Hitchcock that *Edestus* is an intermandibular bony arch carrying teeth is not incompatible with its bilateral symmetry; but we here meet the difficulty already suggested, that *Onychodus*, the only fish known which had such an intermandibular arch of bone, was a scaled Ganoid allied to *Polypterus* and has left abundant bones beside its intermandibular arch. In *Onychodus sigmoides* of the Corniferous limestone, and *O. Hopkinsi* of the Chemung group, the teeth are not anchylosed to the arch, are almost always found detached, and the sides of the arch are compressed between the extremities of the mandibles. In *O. Ortoni*, of the Huron shale, the teeth are implanted in the bony arch as a post is set in the ground, and the arch is not distinctly impressed by the extremities of the mandibles. The type specimen of *O. Ortoni* is yet unique, and we know nothing of the other parts of the fish which bore it. It is, of course, not

impossible that this singular form of dentition might have been borrowed by some Plagiostome which used it to accomplish a similar function; but no facts are yet known to warrant this supposition.

Edestus Davisi is more like the intermandibular crest of *Onychodus* than are the other species of the genus. It is much more curved and the arch of bone from which the denticles rise is laterally compressed or longitudinally grooved. Taken by itself, it renders the suggestion of Miss Hitchcock quite plausible. But it cannot be taken by itself; for wherever that species goes, *E. minor*, *E. Heinrichsi*, and *E. giganteus* must follow, and while we can imagine a fish ten feet long with an arch of bone like *E. Davisi* held between the extremities of the mandibles, it requires a much greater stretch of the imagination to conceive of a shark of such size that this relatively insignificant organ was twenty inches long and seven or eight inches wide. Certainly such a monster would seem very much out of place in the lagoons of the coal marshes. Again, *E. Heinrichsi* is nearly straight, a foot long, rounded and massive at one end, thin and acute at the other; but the succession of denticles was by additions to the acute end, which must have been behind, for if it was situated in the symphysis, the blunt, rounded end would have formed the apex of the arch of the lower jaw; a condition of things scarcely comprehensible.

If, now, we transfer this spine to the position of the post-dorsal fin, and bury it in the soft parts, all except the denticles, the elongation backward by the successive addition of sheaths and denticles becomes intelligible and natural.

There are some other features in this fossil which require notice, viz: There is no distinct line of demarkation between an exposed and a buried portion, such as we find in most of the defensive spines of sharks, unless, as seems probable, all the shaft was buried and only the denticles exposed. Another peculiarity is the absence of the medullary cavity found in most dorsal spines of Sharks. This is quite conspicuous in the spines of *Hybodus*, *Ctenacanthus*, etc.; but in the Rays the spines are solid, and there is little distinction between the exposed and buried parts. The exceptional characters just mentioned need not, therefore, be considered incompatible with the view that these fossils are dorsal spines.

The segmented structure of *Edestus* is its most marked and anomalous feature, but one equally so whether it be considered spine, jaw, rostrum, or intermandibular arch. It is undoubtedly to this structure that we must ascribe the absence of a medullary cavity, as each segment bearing a denticle seems to have been nourished independently of its fellows. It is also apparent that the growth of this organ was by additions to the summit of successive sheaths, each of which carried a denticle. This is strikingly different from the mode of growth of all sharks' spines known, as these increase by additions to the base, and are thus pushed upward and lengthened. The same is true of all rostra which are used as weapons of defense or offense. If we consider the segments of *Edestus* as homologues of a dental series we encounter the same difficulty. A row of teeth of *Orodus*, for example, which consist of enameled crowns with flattened bony bases lying in contact and compressed together, considered as a whole, presents some analogy with our fossils; but there, too, the growth is from behind forward, new teeth moving up to take the places of such as are broken or worn away. The numerous disconnected segments of *Edestus Heinrichsi* furnished me by Mr. Butters seem to prove conclusively that the spine was elongated by the addition of a sheath carrying a denticle to the extremity and under side of the pre-existing series, as shown in Pl. XXXIX, Fig. 2^b. I also have from Vermillion County, Ind., a specimen figured on Pl. XXXIX, Fig. 2^a, which seems to be the basal segment of a spine, probably of a young individual of *Edestus Heinrichsi.* This is a spatulate solid bone, carrying a beautifully perfect enameled denticle at its extremity. The shells or sheaths obtained from Mr. Butters are similar to this, except that each one is a trough, into which the succeeding one fits, and the added cap covers a portion of the enameled base of its predecessor. If this is all true, and it seems undeniable, we are compelled to conclude that the spine was buried in the integuments throughout its entire length, the enameled denticles alone projecting above the surface to form a saw, which would be a terrible weapon if placed upon some flexible portion of the body where it could be used with freedom and power. The extremity of the spine may have lain in a sheath, from which it could be partially erected by muscular action and used as the lancet of the surgeon fish (*Acanthurus*) is; but the bilateral

symmetry of *Edestus* proves that if employed in this manner it must have been located on the upper margin of the tail or back.

The segmented structure of *Edestus* has led Dr. Woodward to compare it with the spines of *Pelecopterus*, and especially with the pectoral spines of this genus described by Prof. E. D. Cope,[1] but the symmetry of *Edestus* forbids the acceptance of this conclusion. The pectoral spines of all fishes are unsymmetrical. This is plainly seen in *Machæracanthus* and *Gyracanthus*, and, as I have lately shown, in the pectoral spines of *Stethacanthus*, (*Physonemus*) *Altonensis*. *Pelecopterus* probably had dorsal as well as pectoral spines, and a comparison with them would be better grounded; but as that was a bony fish, the dorsal spines would have an articulation at the base, and would have grown at the base and not at the summit.

In the spines of *Trygon*, however, we find a much closer resemblance to *Edestus*—one that seems to me to go far towards solving the problem of the relations and functions of these peculiar organs, and almost decides that they are dorsal spines. In *Trygon* a considerable number, sometimes five or six, defensive spines are set in the place of the posterior dorsal fin. They come into use in succession, like the fangs of venomous serpents. As the anterior one loses its denticles or becomes worn or broken it falls and is succeeded by another from behind. Yet several may be in existence and effective at the same time, all rising from a common segmented bony base which grows by additions to its posterior extremity.[2]

All this is true of the spines of *Edestus* if we are right in locating them in the position of the second dorsal fin on the back or tail of a Plagiostome fish.

Hence, until further light shall be thrown upon the interesting question of the homologies and functions of *Edestus*, we may regard them as the post-dorsal spines of large cartilaginous fishes of which the other parts are yet unknown, and may suppose that they were used for attack and defense like the spines of *Trygon* or *Acanthurus*.

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[1] Geol. Survey of the Territories, vol. 2, p. 244 A.

[2] On the tail of *Heliobatis radians*, Marsh, a fresh-water ray from the Eocene Green River beds of Wyoming, I have seen three spines, which must have been in service at the same time; and Gunther (Study of Fishes, p. 190) figures a group of *five* spines in function on the tail of *Aëtobatis narinari*.

EDESTUS GIGANTEUS, n. sp.

Plate XLI, Fig. 1.

Spine very large, eighteen inches or more in length by seven and a half inches in breadth to top of denticles, and two inches in thickness at center; form strongly arched, section spatulate in the middle, lenticular at base; lateral surfaces of bony portion vermicularly roughened; segments narrow, running far back, about three-quarters of an inch wide, in the middle of the spine ten inches from summit of denticle to lower margin; denticles three and a half inches long by two and a quarter inches wide at base; triangular in outline, crown about as broad as high, base prolonged backward and downward into a simple curved point; margins set with fifteen to eighteen strong, rounded, compressed crenulations.

This remarkable spine differs from the other species of the genus not only by its greater size but by the form of its enameled denticles. It approaches nearest to *Edestus vorax*,[1] Leidy, but is distinguished from that species by its larger size, more prolonged segments, and especially by the outline of the bases of the denticles. In *E. vorax* the enameled surface of the denticles is nearly horizontal and is rounded behind, with a deep notch. In the species before us, on the contrary, the enamel runs down obliquely backward to an acute point, from which it sweeps upward by a gentle curve, forming a shallow sinus, to the base of the posterior row of serrations.

From *Edestus Heinrichsi*,[2] N. & W., it differs by its greater size, more curved form, more oblique denticles, and the shorter posterior point of the base.

From *Edestus minor*,[3] Newb. (wrongly named *Edestus vorax* on the page of explanations, opposite the plate in Geology of Illinois, volume 4), it differs in its much greater size and the far broader and less decurrent denticles, as will be seen from the figures now given, reproduced from photographs of the two last-mentioned species.

[1] Described in Proc. Acad. Nat. Sci. Phila., vol. 7, p. 414, and in the Journal of the same Academy, 2d series, vol. 3, 1856 (1858), p. 159, pl. 15.

[2] Geol. Illinois, vol. 4, p. 350, pl. 4, fig. 1.

[3] Ibid., vol. 2, p. 84, pl. 4, fig. 24; vol. 4, pl. 1, fig. 2.

Formation and locality: Coal Measures, Decatur, Macon County, Ill. Collected by Mr H. A. Wheeler, of Washington University, Saint Louis, to whom I owe the opportunity of examining and describing it.

Ctenodus serratus, Newb.

Plate XXVII, Fig. 31.

Ctenodus serratus, N.; Palæontology of Ohio, vol. 2, p. 59, pl. 58, figs. 15, 16.

Teeth of lower jaw of medium size, sixteen lines long by nine lines wide, somewhat triangular in outline; crown marked with eight prominent and sharp radiating ridges, which terminate above in numerous compressed, acute denticles, the furrows between the ridges being pitted to receive corresponding denticles of the opposite teeth. These ridges and furrows vary much in length, so that the end of the tooth forms a long-pointed triangle, and at the opposite extremity the crown is rounded and the base projects in a depressed and flattened point.

In general form and marking this tooth bears considerable resemblance to that of *Ct. obliquus* of the Northumberland coal-fields, England, but the ridges are more numerous and much narrower. From the larger species of *Ctenodus* found in England, *Ct. tuberculatus*, etc., it will at once be distinguished by the fan-like radiation of its ridges, which all center at the most prominent point of the crown. When in its perfect condition this is the most elegant species of the genus yet discovered. It is characterized by a remarkable exactness of form and sculpture. The internal margin forms a graceful arch, from which the prominent point of the base projects at the end of the tooth where the ridges are shortest. The denticles which crown the ridges are much compressed, very sharp, and somewhat curved outward.

Formation and locality: Coal Measures; Linton, Ohio.

Ctenodus Ohioensis, Cope.

Prof. Edward Cope, in 1874, briefly described in the Proceedings of the Academy of Natural Sciences, Philadelphia, a portion of the cranial bones of a species of *Ctenodus* from the Coal Measures of Linton, Ohio. He called the species *Ct. Ohioensis*, and illustrated it further in the Palæontology of

Ohio, volume 2, page 410, Pl. XLV. I had previously obtained a more nearly complete cranium of this fish, and I now give below an outline sketch of it, half natural size.

The reference of these crania to *Ctenodus* is not based upon the discovery of teeth associated with them, but upon their marked resemblance to the crania figured by T. P. Barkas in his Atlas of Carboniferous Fossils, Pl. X, Figs. 244–246, and upon descriptions of the remains of this genus by Hancock and Atthey in the Annals and Magazine of Natural History, and in the Transactions of the Tyneside Naturalist's Field Club.

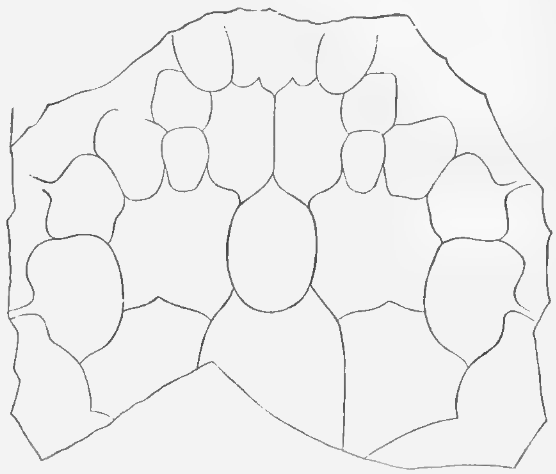

FIG. 3. Ctenodus Ohioensis, Cope. Outlines of cranial plates; ½ natural size.

On the preceding pages of this memoir I have pointed out the difficulty we find in separating *Dipterus*, *Ctenodus*, and *Ceratodus* by the teeth alone; but it is probable that the crania, where available, will furnish satisfactory distinctive characters. In this connection a comparison of the figure of the tessellated cranium of *Dipterus*, given by Pander in his Ctenodipterinen, Pl. III, Fig. 1, with the diagram now published, will be suggestive. Though very much alike, it will be seen that they present differences which may well have generic value.

I will conclude my remarks on our Coal Measure fishes with a few notes on species which have been imperfectly described elsewhere, or which are new but can not be fully described without more material.

Cœlacanthus ornatus, Newb. This is a small species found at Linton, Ohio, where it is very rare. It is briefly described in the Palæontology of Ohio, vol. 1, p. 340. Since the publication of that volume I have obtained several other specimens and find that it may be readily identified by its small size, relatively large cranial tubercles, and very thin, delicate scales *on which the raised lines are parallel* and do not converge as in *C. elegans* and *C. robustus*.

Cœlacanthus robustus, Newb. Of this species no complete, nor even good specimens, have yet been obtained, though scales, opercula, jugulars, etc, are common in the cannel coal at Linton, Ohio. It was a foot or more in length, and apparently quite distinct from the smaller species with which it is associated.

Rhadinichthys ? lineatus, Newb. The little Palæoniscoid fish which I described in the Palæontology of Ohio, vol. 1, p. 353, as *Eurylepis lineatus* should be separated from that genus and probably be included in *Rhadinichthys*, Traquair. The same should, perhaps, be done with my *Eurylepis corrugatus*. Both these differ from the typical species of *Eurylepis*, with which they are associated at Linton, by the narrowness of their scales (vertically) and the linear ornamentation of *all* the head bones. In *Eurylepis* proper the cranial surface is always tuberculated. In *Eurylepis lineatus* the scales on the sides are quadrangular and about as high as long. In *E. corrugatus* the side scales are about twice as high as long. In both these species the scales are smooth and polished, and over the abdominal portions of the body are very narrow; hence are more numerous in each vertical row than in the true Eurylepids. Whether they should be included in Dr. Traquair's genus *Rhadinichthys* can be decided only by a comparison of specimens, which has not yet been possible.

Euctenius, sp. At Linton I have found several specimens of what Prof. Anton Fritsch calls *Kammplatten*. He has found them in the Upper Carboniferous rocks near Stuttgart, and considers them the cloacal appendages of Amphibians. Dr. R. H. Traquair obtained them from the Coal Measures of Scotland, and named them *Euctenius*, supposing them to be the teeth of fishes. They are well named *Kammplatten*, for they are beautiful little combs half to three-fourths of an inch long, with exquisitely cut and polished teeth. Sometimes the comb proper is attached to a kind of handle as long as itself; such specimens resemble minute mandibles of fishes, like *Callognathus*, described in this memoir; I have other specimens in which the combs are set side by side, as many as nine or ten in a series, and two groups are associated in the relative positions of the palate teeth of *Ctenodus*. With these in view it will require strong evidence to convince me that these singular objects are not the dental organs of fishes.

PLATES.

PLATE I.

PLATE I.

TITANICHTHYS AGASSIZII, Newb. (p. 133).

FIG. 1. Basal portion of cranium and supra-scapulas; outside.
2. Inside of cranium and supra-scapulas.
Both figures one-seventh natural size, linear.
Cleveland shale, Sheffield, Lorain County, Ohio.

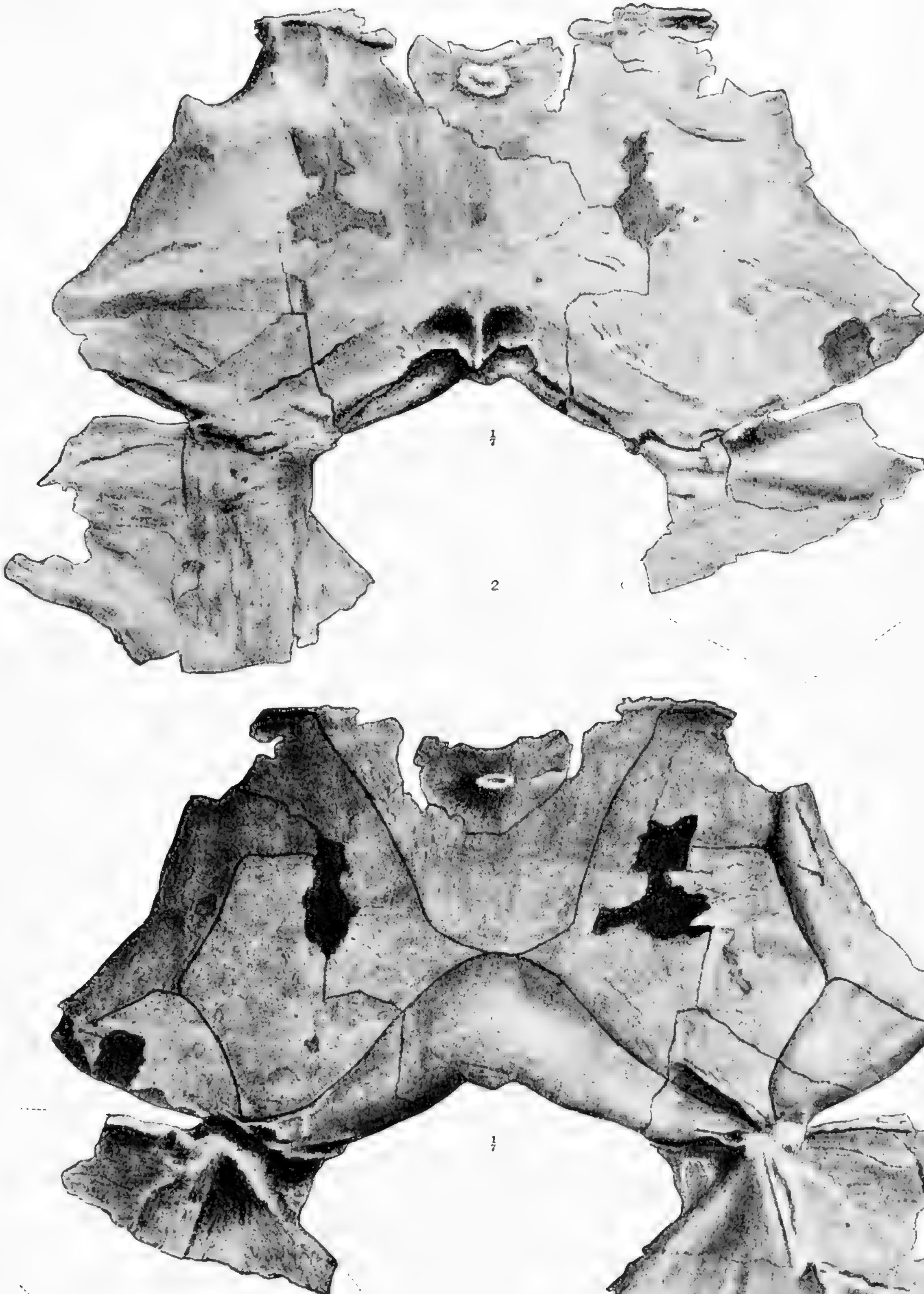

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PLATE II.

PLATE II.

TITANICHTHYS AGASSIZII, Newb. (p. 133).

FIG. 1. Mandible, outside.
2. Mandible, inside.

TITANICHTHYS CLARKII, Newb. (p. 133).

3. Mandible, outside.
4. Mandible, inside.

All one-quarter natural size, linear.
1, 2, Cleveland shale, Sheffield, Lorain County, Ohio.
3, 4, Cleveland shale, Berea, Cuyahoga County, Ohio.

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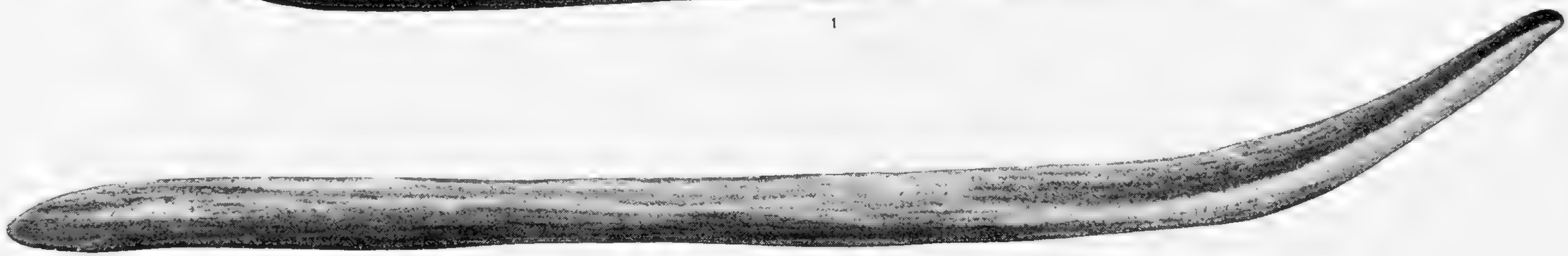

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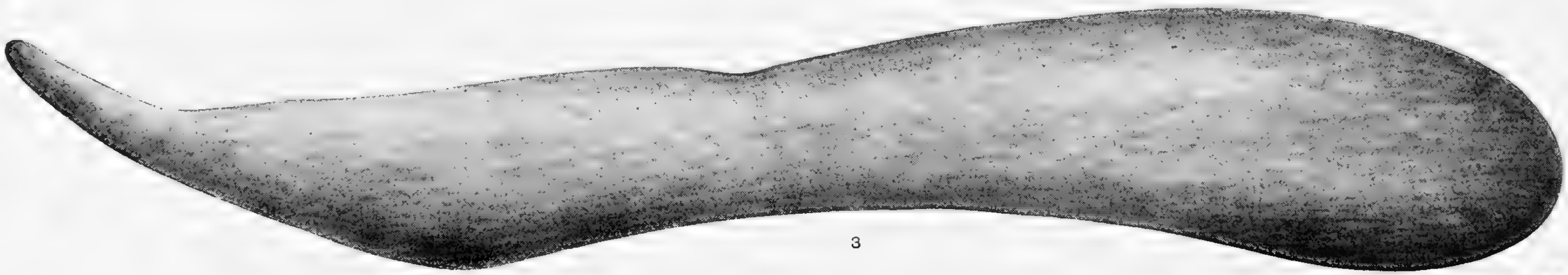

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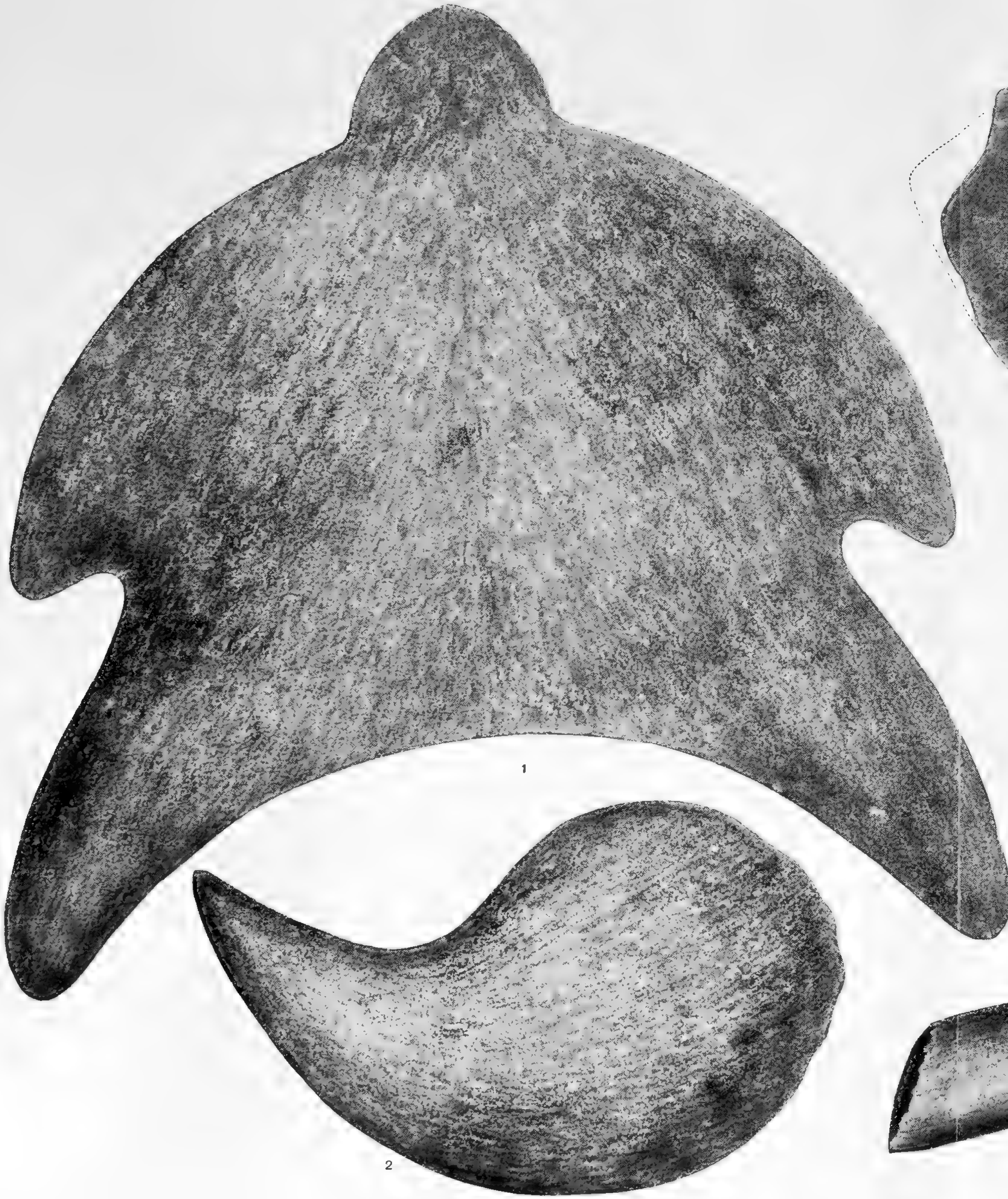
PLATE III.

PLATE III.

TITANICHTHYS CLARKII, Newb. (p. 133).

FIG. 1. Ventral ? plate.
2. Suborbital plate.
3. Coracoid ?.
4. Supra-scapula seen from above, showing condyle of articulation with angle of cranium.
5. Posterior angle of head seen from behind, showing horizontal socket of articulation with supra-scapula.

All one-fifth natural size, linear.



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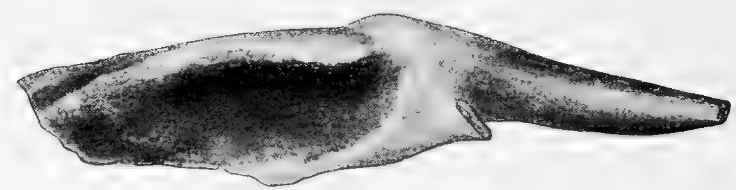

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PLATE IV.

PLATE IV.

DINICHTHYS TERRELLI, Newb.

FIG. 1. Cranium from outside, one-sixth natural size, linear.
2. Cranium from inside, one-sixth natural size, linear.

TITANICHTHYS CLARKII, Newb. (p. 133).

3. Suborbital plate, one-ninth natural size.

TITANICHTHYS AGASSIZII, Newb. (p. 133).

4. Suborbital plate outside, one-seventh natural size, linear.
Cleveland shale, Lorain County, Ohio.

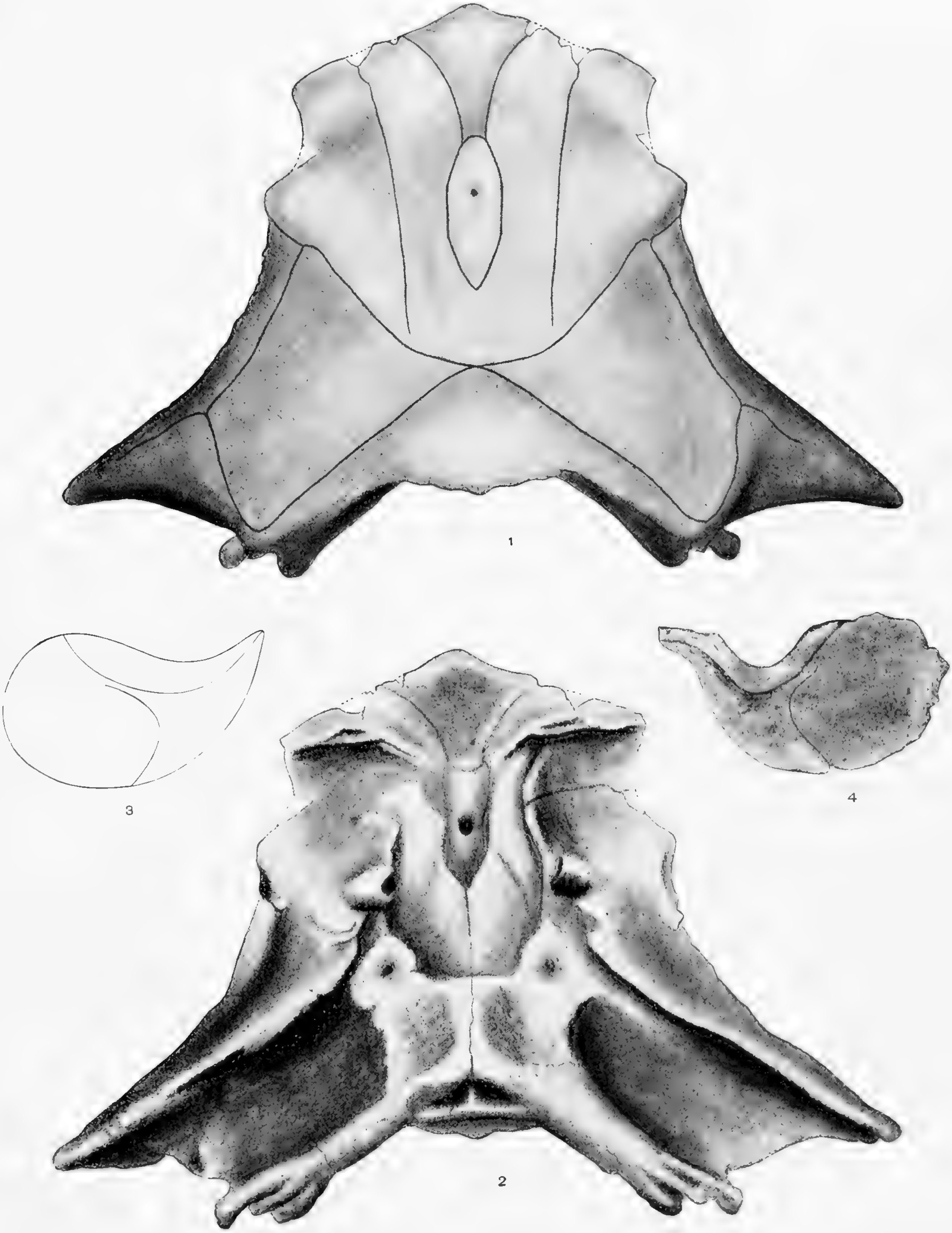

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PLATE V.

PLATE V.

DINICHTHYS TERRELLI, Newb.

FIGS. 1, 2. Right and left pectoral spines, natural size.
Cleveland shale, Lorain County, Ohio.

3. Hyoid ? plate, natural size.
Cleveland shale, Sheffield, Ohio.

DINICHTHYS INTERMEDIUS, Newb. (p. 152).

4, 5. Right and left pectoral spines, natural size.
Cleveland shale, Cleveland, Ohio.

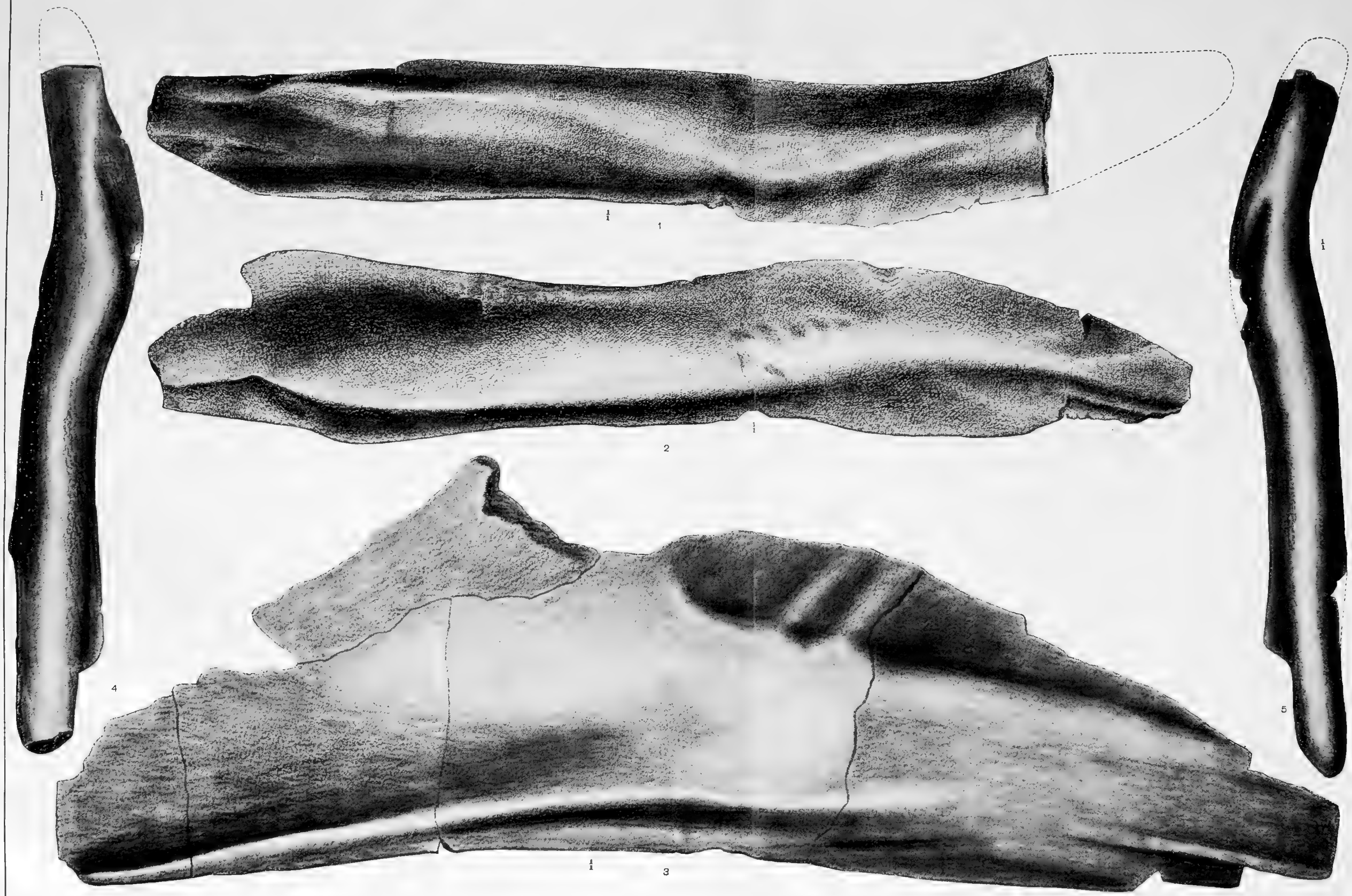

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PLATE VI.

PLATE VI.

DINICHTHYS TERRELLI, Newb.

FIGS. 1, 1ª. Jugular plates, one-half natural size.
2, 2ª. Post-clavicular ? plates, one-half natural size.
All from Cleveland shale, Sheffield, Ohio.


1


1a


2


2a

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PLATE VII.

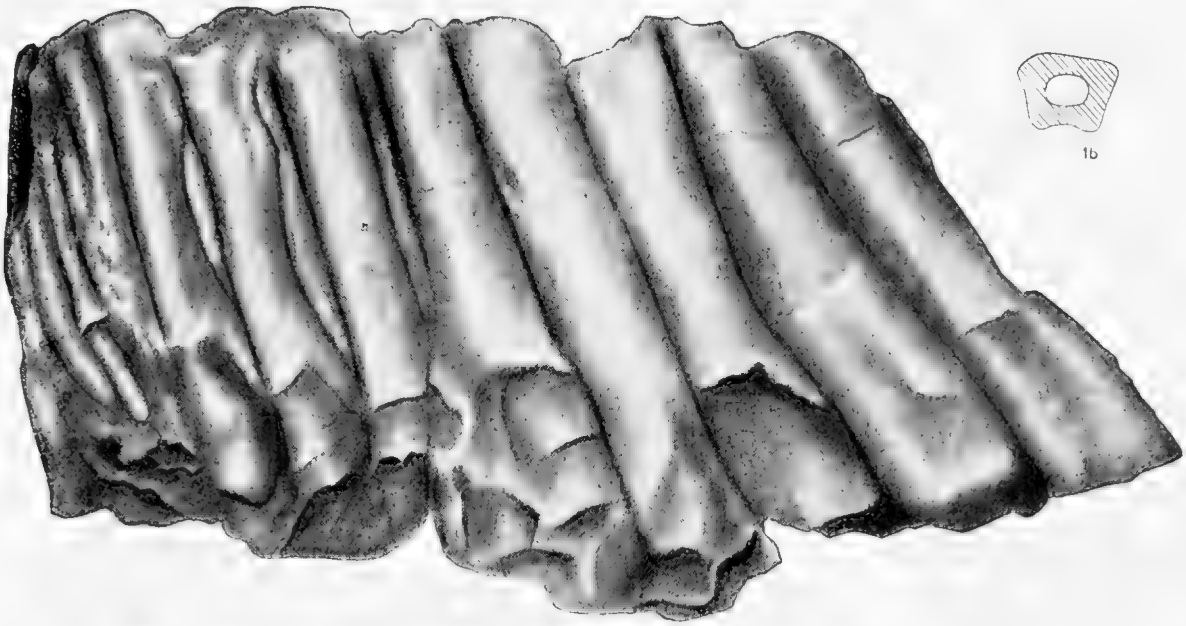
PLATE VII.

DINICHTHYS TERRELLI, Newb.

FIG. 1. Fin rays.
1a. Detached ray.
1b. Transverse section of 1a.
2. Eye capsule, side view.
2a. Eye capsule seen from above.
All natural size. Cleveland shale, Sheffield, Ohio.

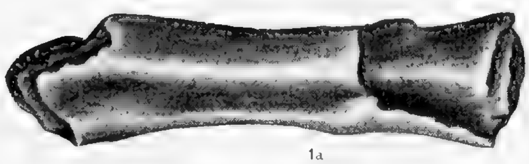
DINICHTHYS CORRUGATUS, Newb. (p. 151).

3. Anterior portion of mandible from inside.
3a. Outside of Fig. 3.
4. Diagram of lens of eye of salmon enlarged, after Owen.
Cleveland shale, Sheffield, Ohio.

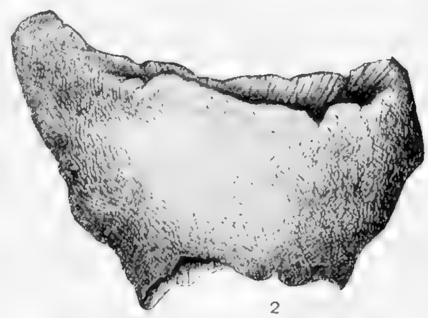


1b

1



1a



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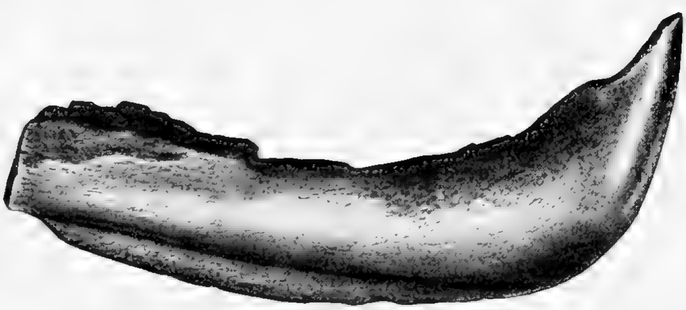

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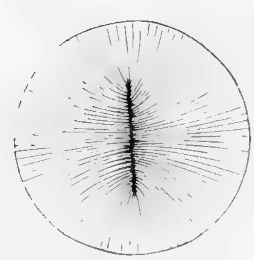

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PLATE VIII.

PLATE VIII.

DINICHTHYS MINOR, Newb. (p. 149).

FIG. 1. Dorsal shield from above.
2. Dorsal shield side view.
3. Supra-occipital bone, outside.
4. Supra-occipital bone, inside.
5. Mandible, outside.
6. Mandible, inside.
7, 8. Premaxillary tooth, front and side views.
All natural size. Cleveland shale, Lorain County, Ohio.

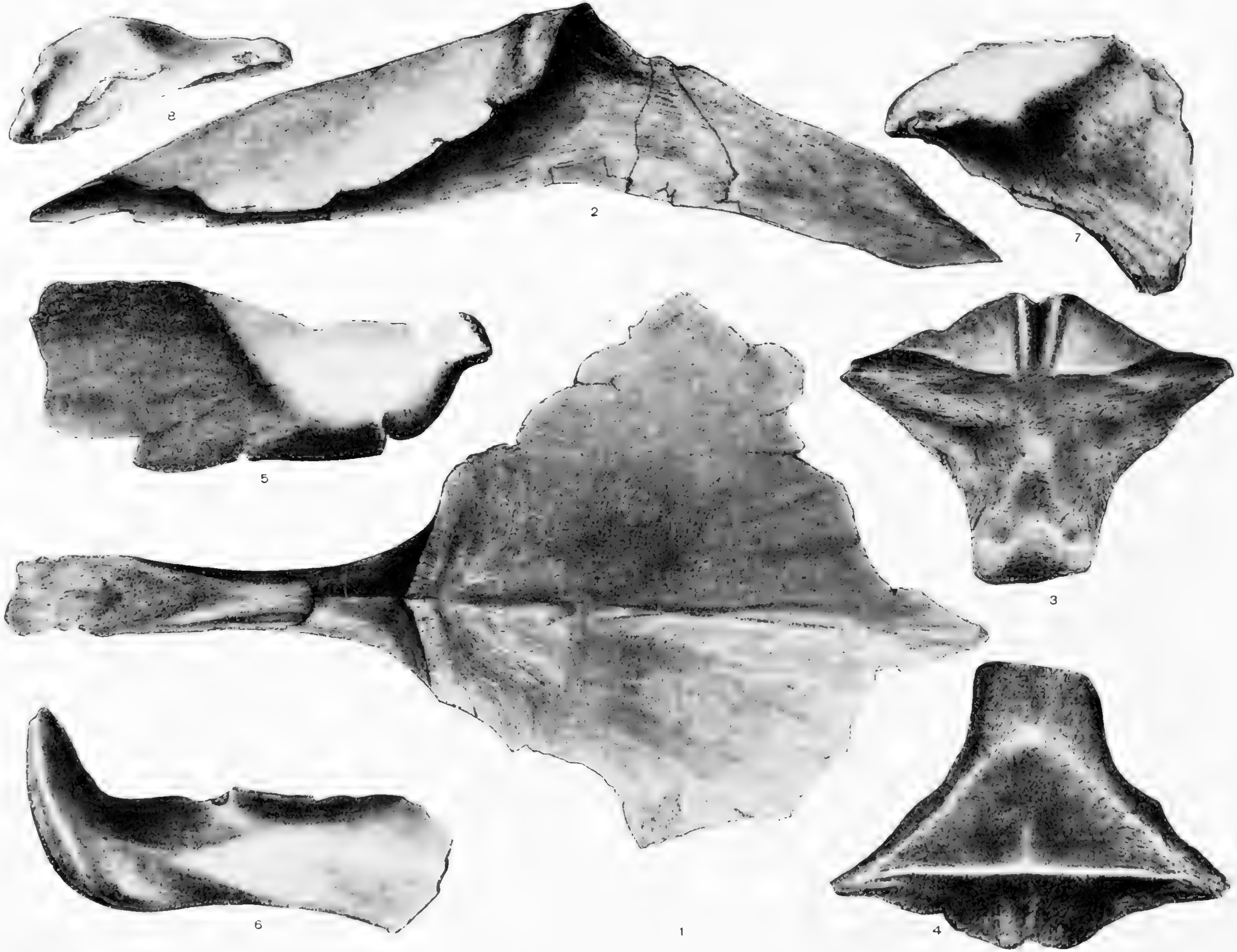

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PLATE IX.

PLATE IX.

DINICHTHYS GOULDII, (p. 150).

FIG. 1. Circle of sclerotic plates.
2. Premaxillary tooth.
3. Supra-scapula, outside.
4. Suborbital plate, outside, natural size.
5. Anterior extremity of mandible.
Cleveland shale, Berea, Ohio.

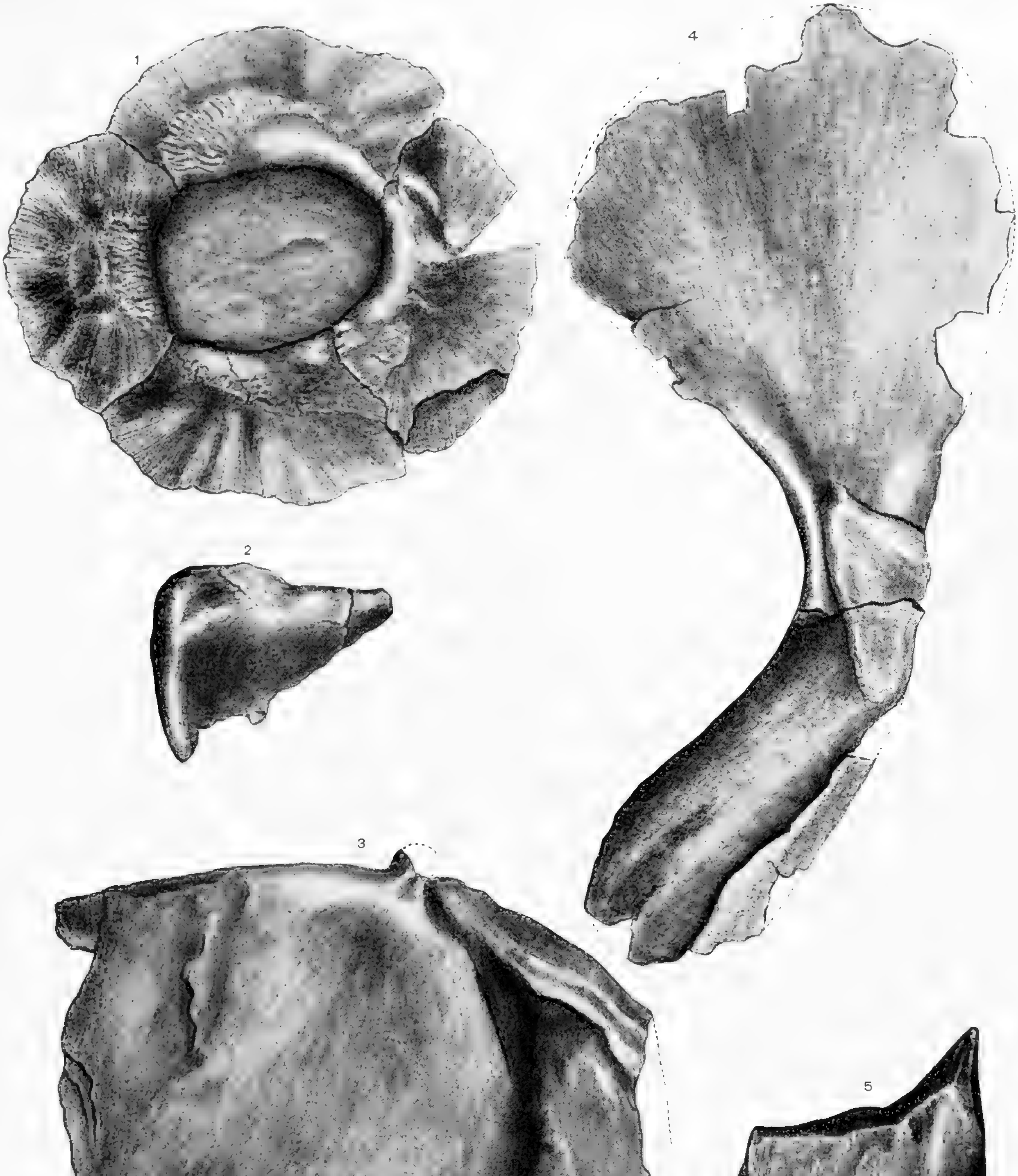

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PLATE X.

PLATE X.

DINICHTHYS INTERMEDIUS, Newb. (p. 152).

FIG. 1. Mandible, inside view.
2. Mandible, outside view.
Half natural size.
Cleveland shale, Sheffield, Lorain Co., Ohio.

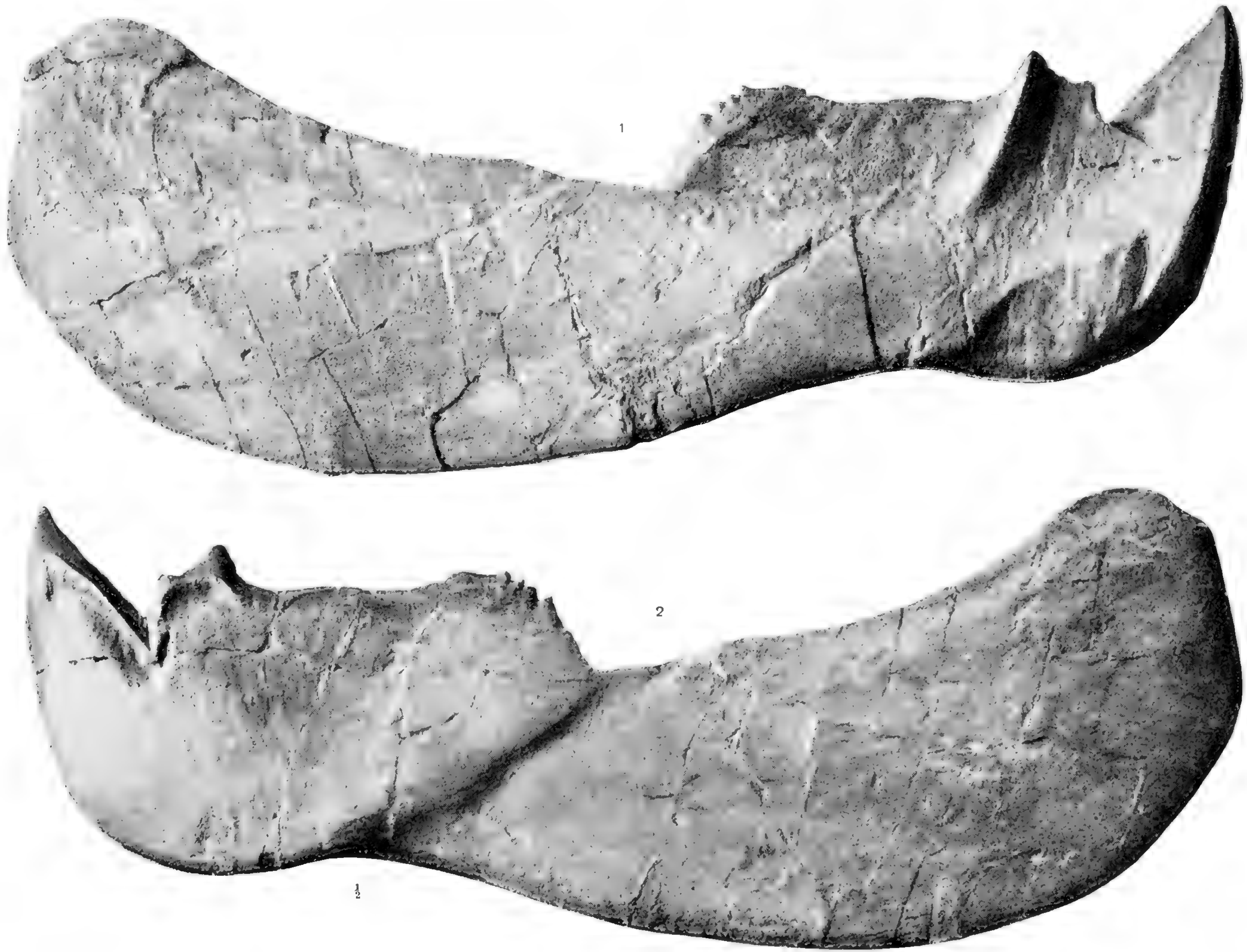

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PLATE XI.

PLATE XI.

DIPLOGNATHUS MIRABILIS, Newb. (p. 159).

FIG. 1. Right dentary bone, outside.
2. Right dentary bone, inside.
3. Right dentary bone, from above.
4. Left dentary bone of another individual, seen from inside and showing deep pit for insertion of ligament at symphysis.

All two-thirds natural size. Cleveland shale, Sheffield, Ohio.

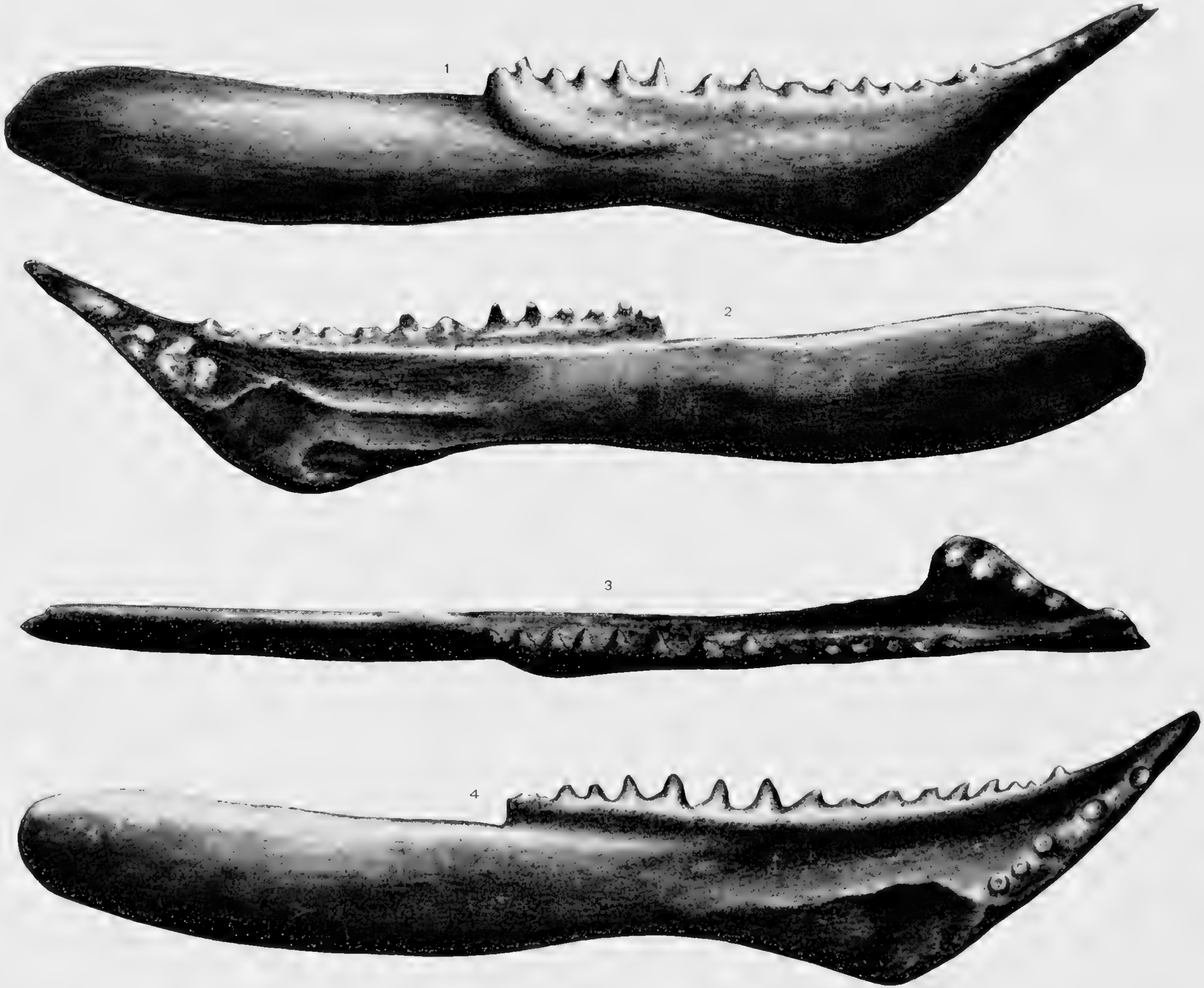

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PLATE XII.

PLATE XII.

DIPLOGNATHUS MIRABILIS, Newb. (p. 159).

FIG. 1. Anterior half of dentary bone, inside, showing pit for ligament at symphysis.
2. Same specimen, seen from above.
3. Same specimen, seen from outside.
All natural size. Cleveland shale, Sheffield, Ohio.

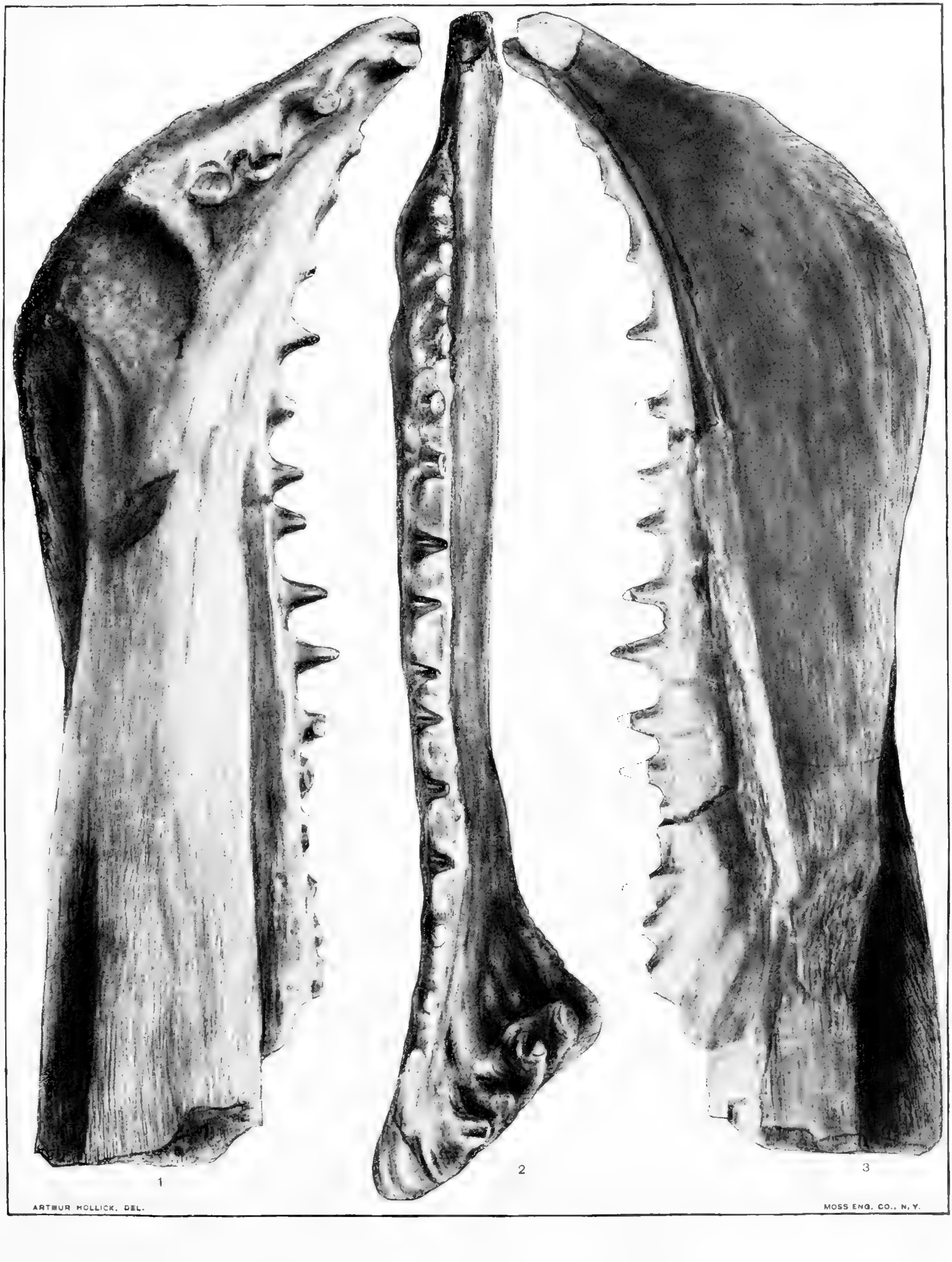
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PLATE XIII.

PLATE XIII.

GLYPTASPIS VERRUCOSUS, Newb. (p. 158).

FIG. 1. Ventromedian plate, one-half natural size.
2. Lateral plate from dorsal ? surface, natural size.

MYLOSTOMA VARIABILIS, Newb. (p. 165).

3, 4. Upper palate teeth, natural size.
5. Crown of peculiar inferior conical tooth, natural size.
All from Cleveland shale, Sheffield, Ohio.

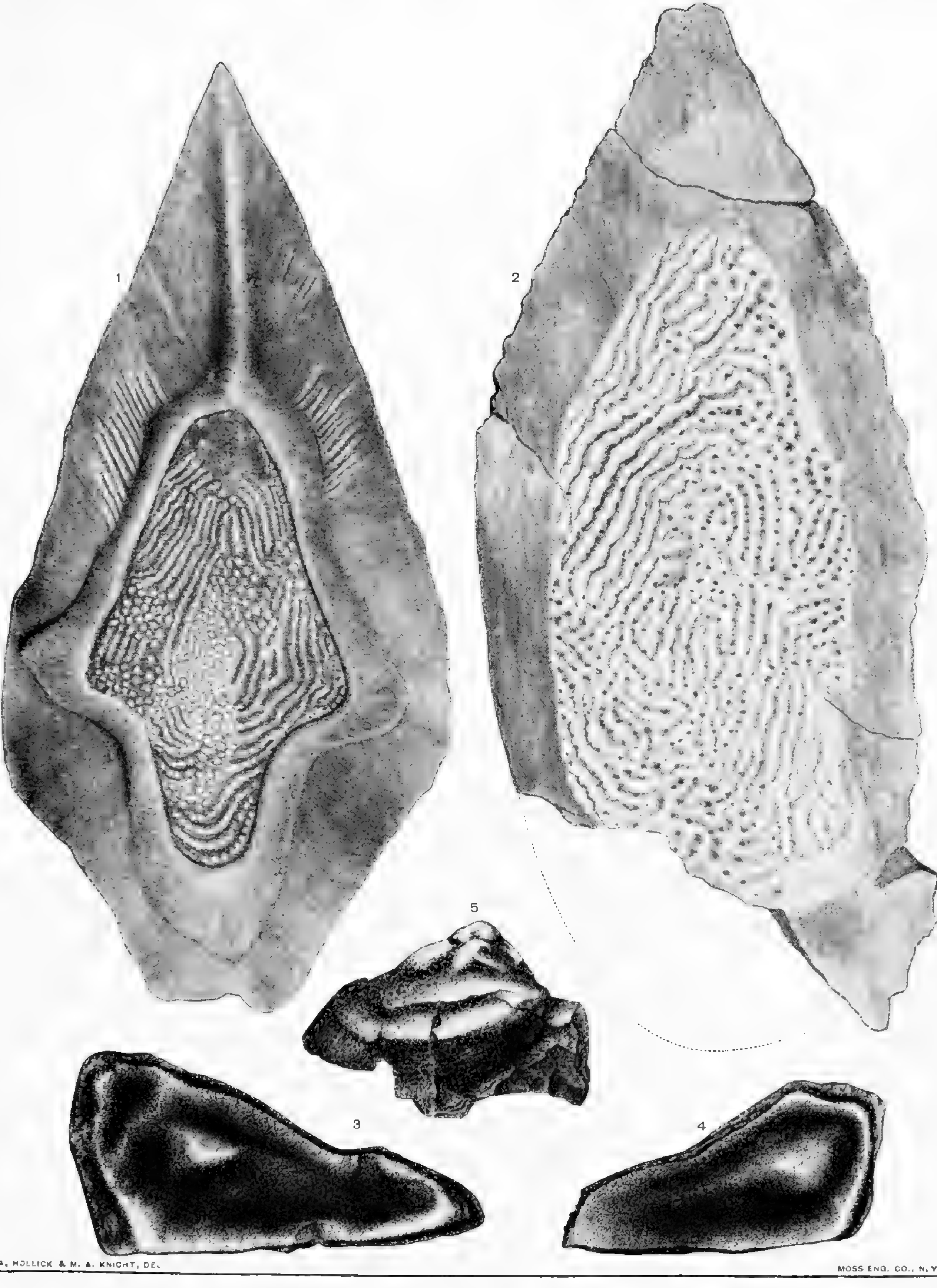

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PLATE XIV.

PLATE XIV.

MYLOSTOMA TERRELLI, Newb. (p. 164).

FIG. 1. Side view of anterior portion of dentary bone.
2. Top view of anterior portion of dentary bone.
All natural size. Cleveland shale, Sheffield, Ohio.

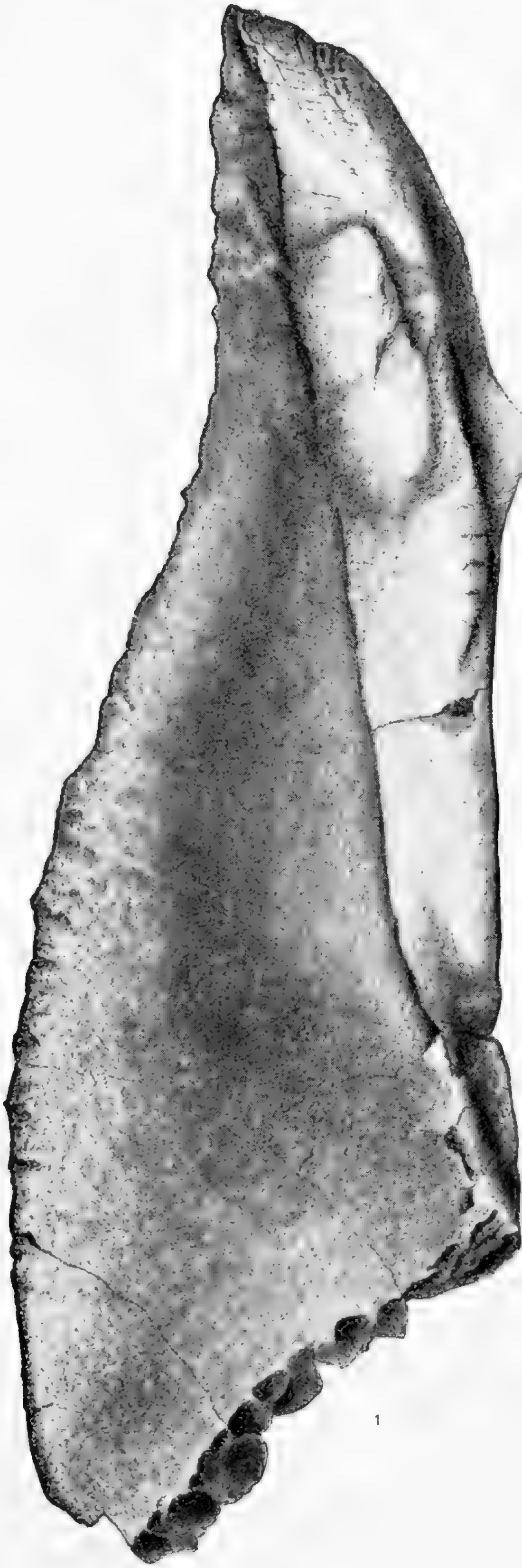

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PLATE XV.

PLATE XV.

MYLOSTOMA VARIABILIS, Newb. (p. 165).

FIGS. 1, 2, 3. Different views of mandibular teeth.

4–5[a]. Side and vertical views of palate teeth.

All natural size. Cleveland shale, Sheffield, Ohio.

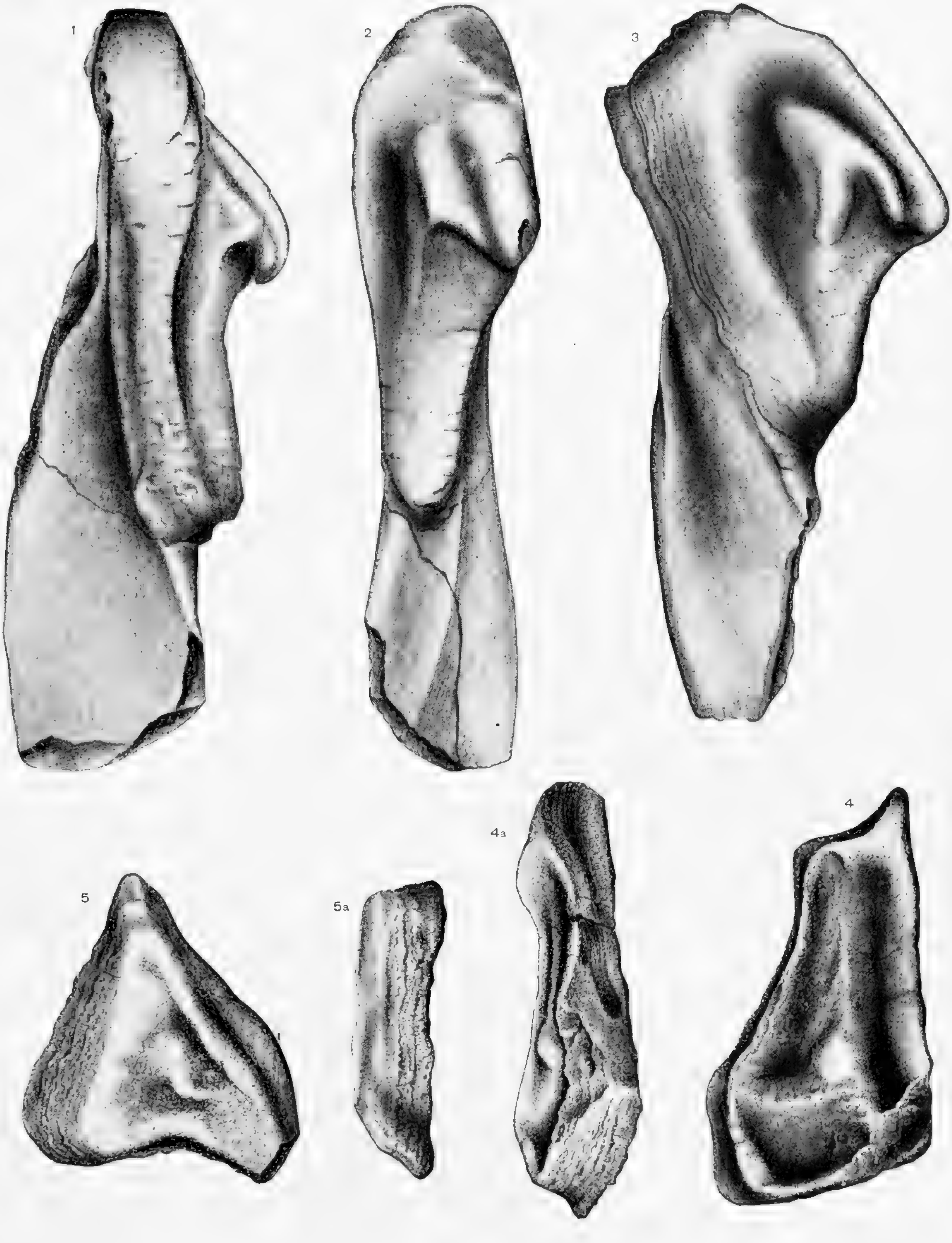

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PLATE XVI.

PLATE XVI.

MYLOSTOMA VARIABILIS, Newb. (p. 165).

FIGS. 1, 2. Side and top views of entire dentary bone, natural size.
3. Dental plate of another individual, seen from above.
4. Pair of triangular teeth, probably from under jaw, and located anterior to Figs. 1, 2.
All natural size. Cleveland shale, Lorain County, Ohio.

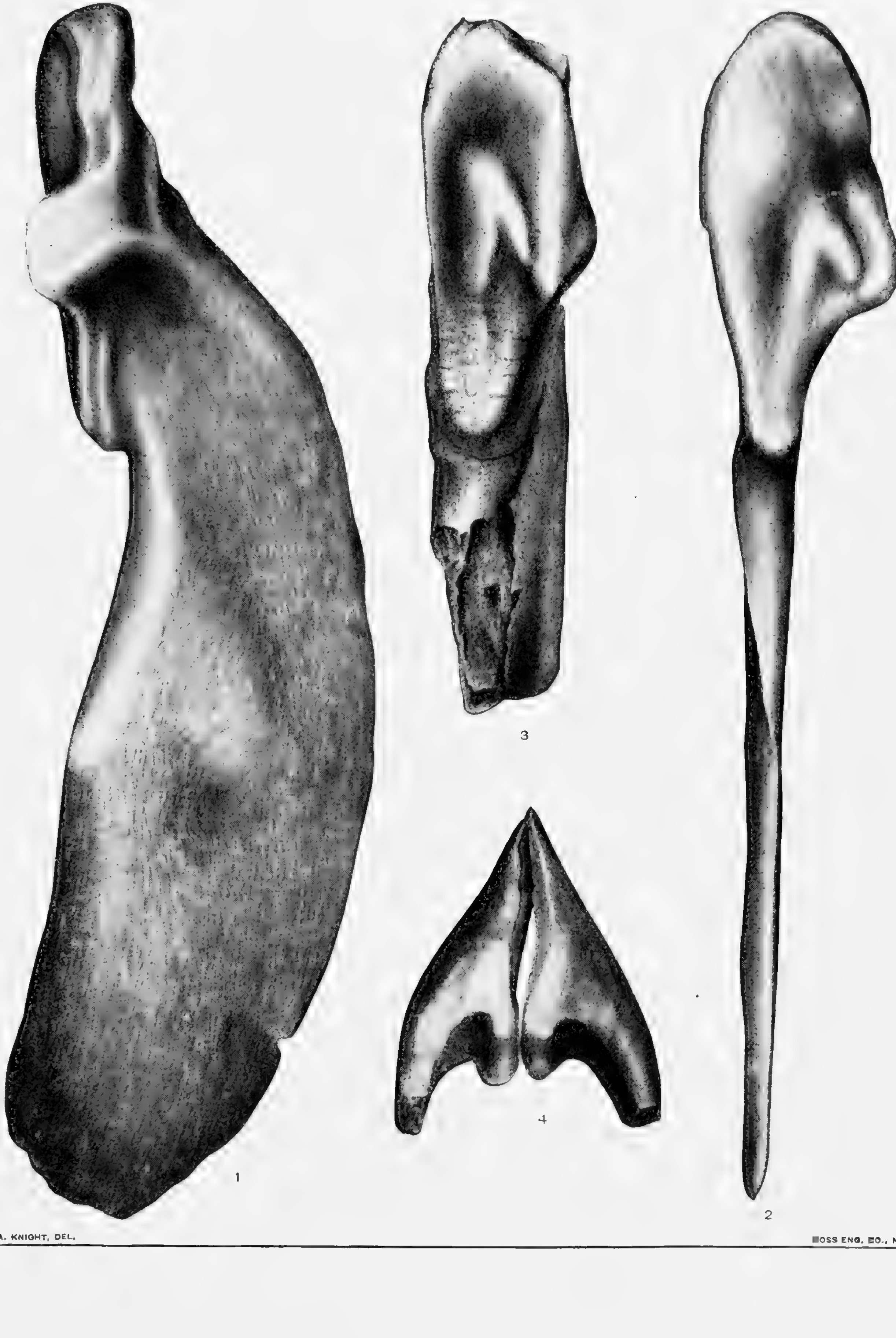

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PLATE XVII.

PLATE XVII.

HOLONEMA RUGOSA, Claypole (sp.). (p. 93).

FIG. 1. Lateral plate of plastron ?, natural size.
2. Central plate of plastron ?, half natural size.
3. Portion of central plate of carapace ?, natural size.
4. Portion of lateral plate of carapace ?, natural size.
All from Chemung group of southwestern New York and northwestern Pennsylvania.

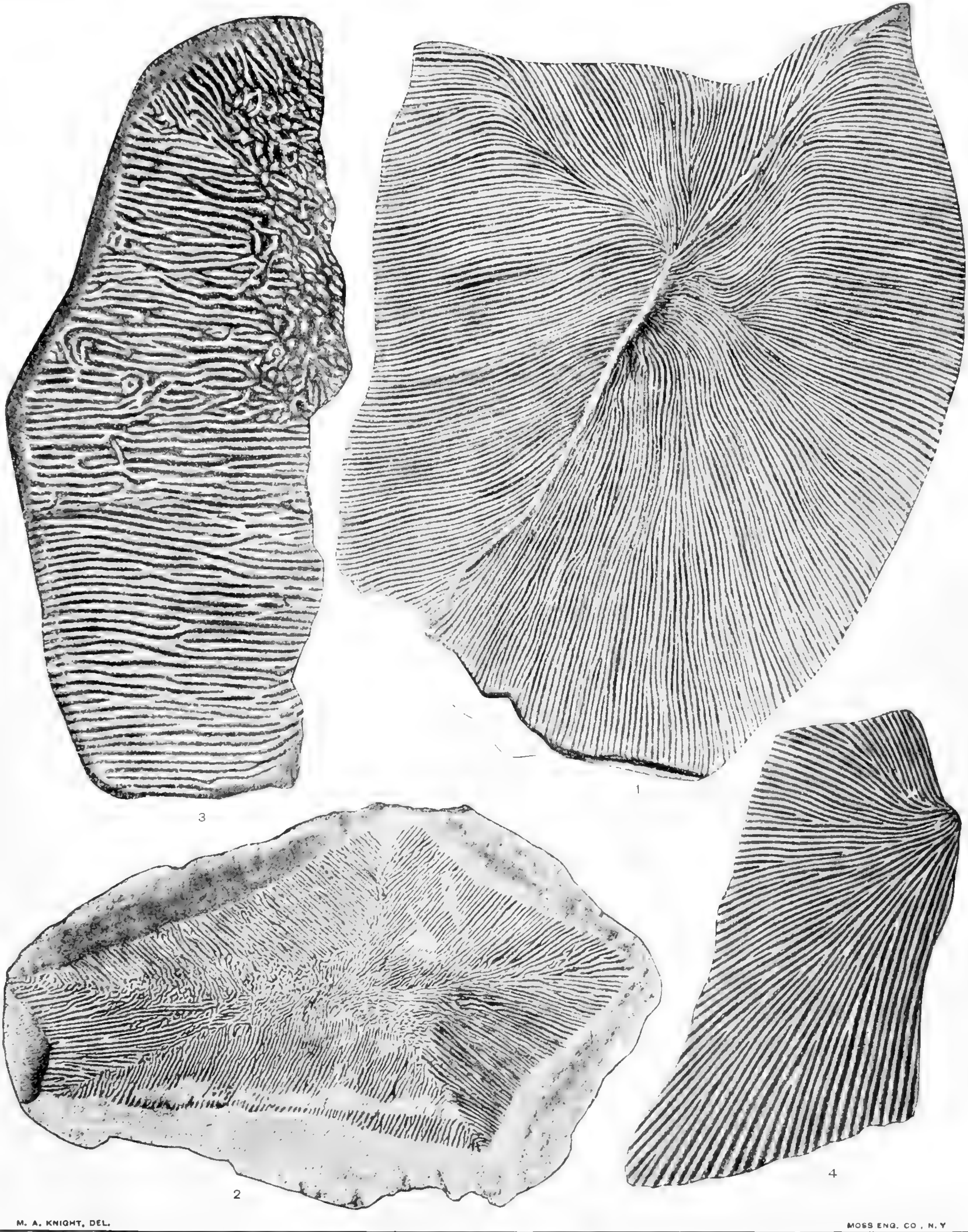

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PLATE XVIII.

PLATE XVIII.

GLYPTOPOMUS SAYREI, Newb. (p. 116).

FIG. 1. Head and anterior portion of body, under side, showing two jugular plates and four lateral jugulars; also lobate pectoral fins. On the same slab are seen portions of two other individuals of the same species. Half natural size.
Catskill group, Susquehanna River, near mouth of Mehopany.

BOTHRIOLEPIS LEIDYI, Newb. (p. 111).

2. Portion of anterior lateral body plate, outside, natural size.
Catskill group, Mansfield, Tioga County, Pa.

HELIODUS LESLEYI, Newb. (p. 86).

3. Upper dental plate.
Chemung rocks, northern Pennsylvania.

GYRACANTHUS SHERWOODI, Newb. (p. 119).

4. Denuded spine, natural size.
4[a]. Portion of side, showing ornamentation.
4[b]. Section.
Green Catskill Sandstone, Lamb's Creek, Tioga County, Pa.

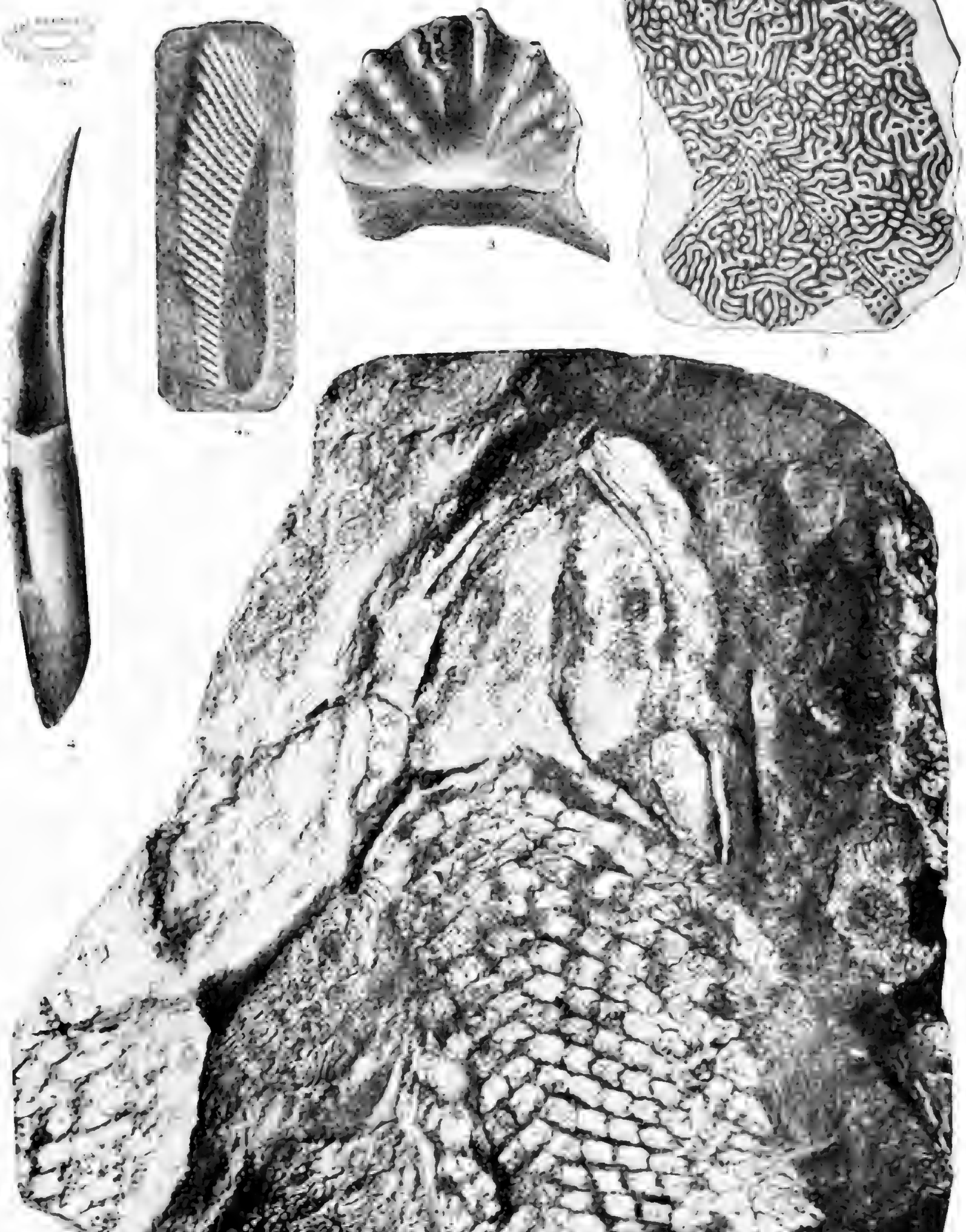

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PLATE XIX.

PLATE XIX.

ONYCHODUS ORTONI, Newb. (p. 71).

FIG. 1. Intermandibular bone, with teeth, side view.

1a. Section of same.

Huron shale, Perry, Franklin County, Ohio.

GANORHYNCHUS BEECHERI, Newb. (p. 95).

2. Labial margin of upper jaw.

Chemung group, Warren, Pa.

ANTLIODUS ARCUATUS, N. & W. (p. 208).

3. Tooth, outside.

4. Inside view of larger specimen.

Saint Louis limestone, Greencastle, Ind.

POLYRHIZODUS LITTONI, N. & W. (p. 209).

5, 6, 6a. Tooth, outside, inside and section.

Greencastle, Ind.

PSAMMODUS GLYPTUS, St. J. & W. (p. 210).

7, 8. Teeth, upper surface.

Greencastle, Ind.

LABODUS MARGINATUS, Newb. (p. 198).

9. Palate tooth, crown surface.

Greencastle, Ind.

DINICHTHYS, sp. ?

10, 10a, 10b. Three views—front, rear, and profile—of premaxillary.

PHYLLOLEPIS DELICATULA, Newb. (p. 97).

11. Scale or scute, natural size.

Chemung group, Bradford County, Pa.

HOLOPTYCHIUS AMERICANUS, Leidy (p. 113).

12, 13. Scales, natural size.

Catskill, Tioga County, Pa.

HOLOPTYCHIUS TUBERCULATUS, Newb. (p. 101).

14. Scale, natural size.

Chemung group, Leroy, Pa.

HOLOPTYCHIUS GIGANTEUS ?, Ag. (p. 101).

15, 16. Scales, natural size.

Catskill, Tioga County, Pa.

ORTHOPLEURODUS CARBONARIUS, N. & W. (sp.) (p. 200).

17. Terminal tooth, upper surface, natural size.

Coal Measures, Carlinville, Ill.

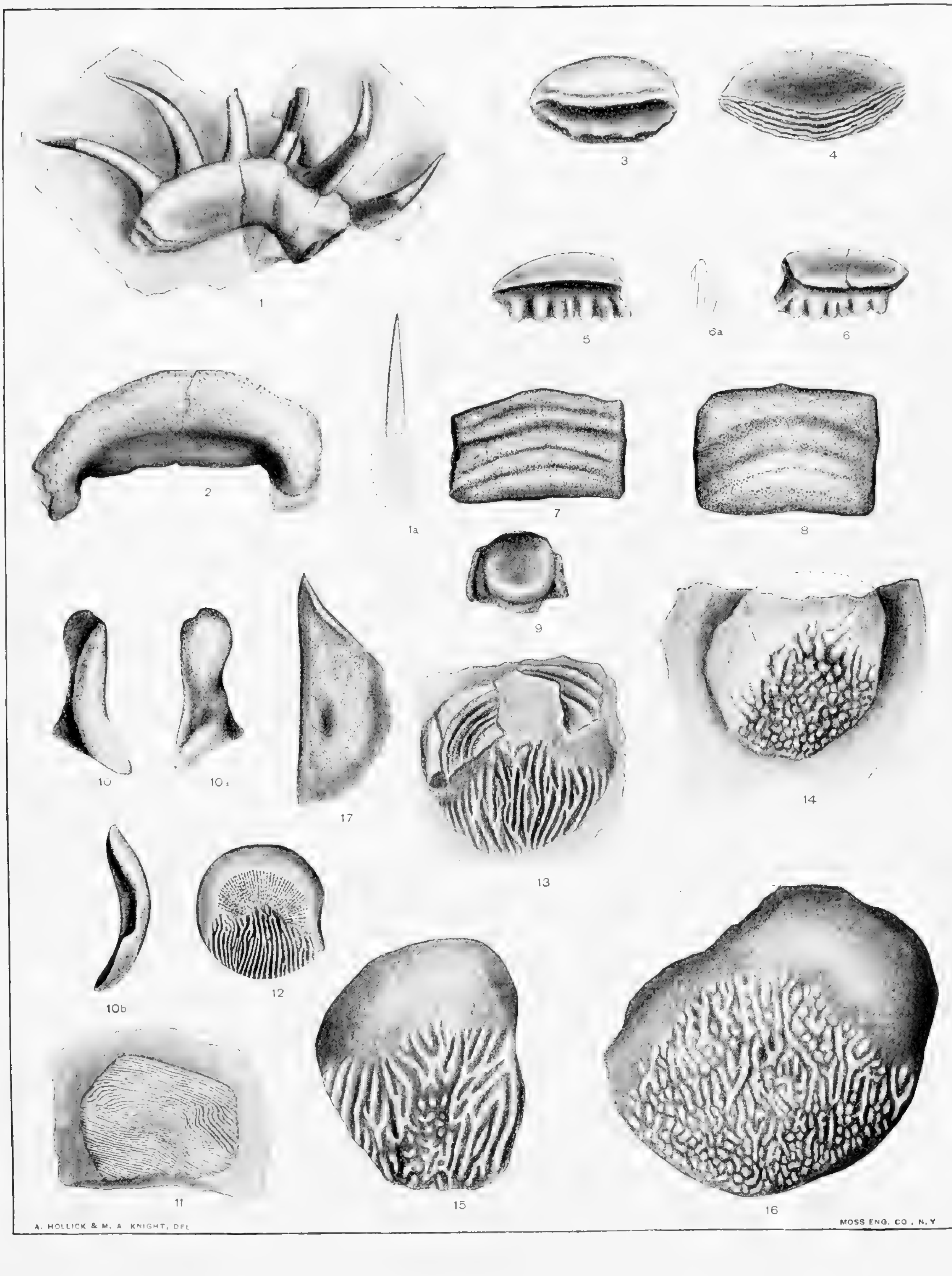

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PLATE XX.

PLATE XX.

BOTHRIOLEPIS LEIDYI, Newb. (p. 111).

FIG. 1. Pectoral spine and inside of left anterior ventral plate.
2. Narrow pectoral spine.
3. Head with dumb-bell aperture.
4. Dorsal scute, outside.
5. Dorsal scute, partially denuded, showing keel of under surface.

BOTHRIOLEPIS MINOR, Newb. (p. 112).

6–8. Scutes, upper and lower surfaces.
Chemung group, Leroy, Pa.

HOLOPTYCHIUS GRANULATUS, Newb. (p. 100).

9. Scale, outside.

HOLOPTYCHIUS HALLII, Newb. (p. 114).

10, 10a. Scales, natural size and enlarged.

HOLOPTYCHIUS PUSTULOSUS, Newb. (p. 100).

11, 11a. Scales, outside and inside.

HOLOPTYCHIUS RADIATUS, Newb. (p. 115).

12–14. Scales, natural size.
Catskill group, Blossburgh, Pa.

SPHENOPHORUS LILLEYI, Newb. (p. 92).

15. Clavicle?.
Chemung group, Bradford County, Pa.

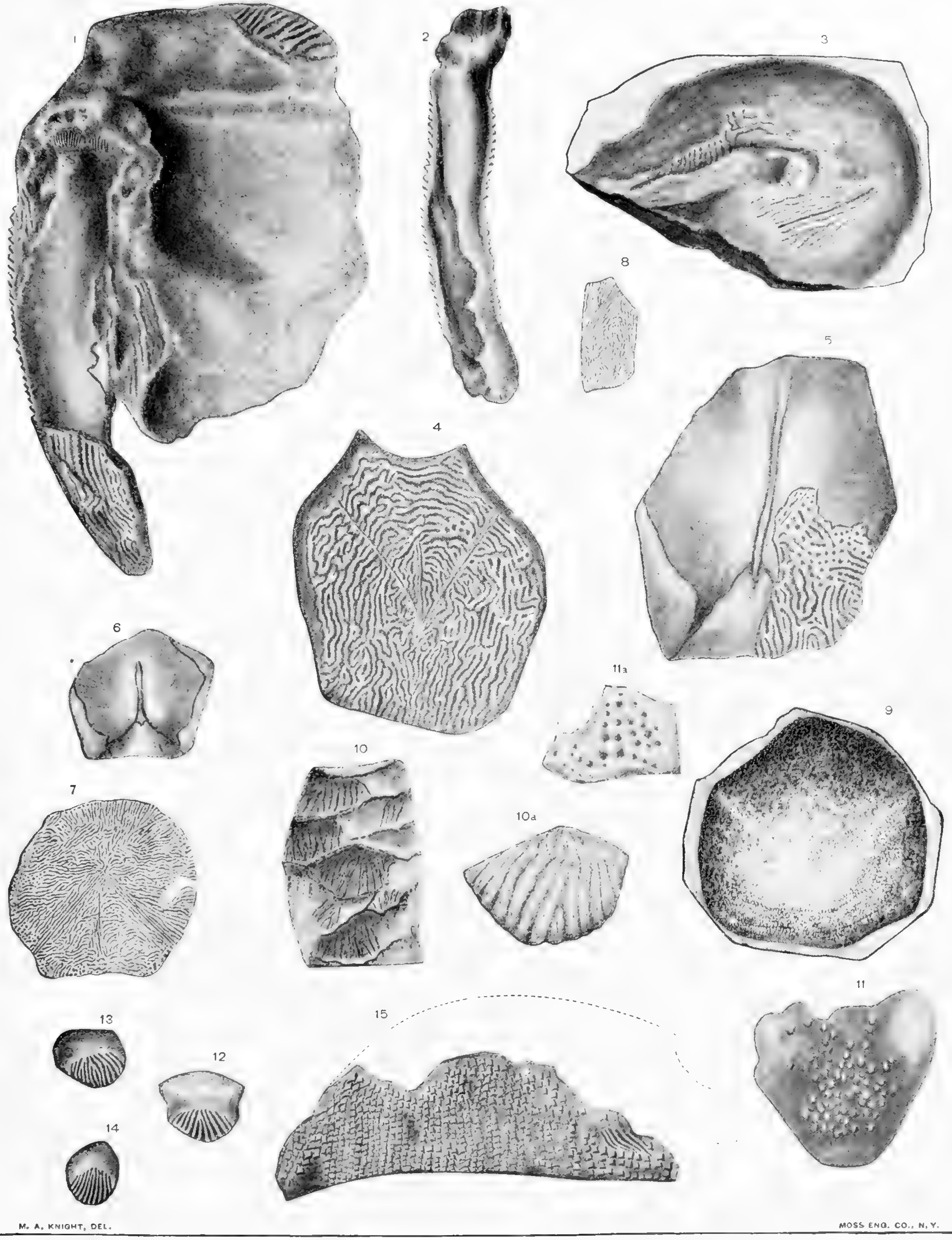

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PLATE XXI.

PLATE XXI.

MAZODUS KEPLERI, Newb. (p. 180).

FIGS. 1–3. Teeth, all natural size.
Berea shale, Berea, Ohio.

HETERACANTHUS POLITUS, Newb. (p. 66).

4, 5. Summit and base of spine, natural size.
4a. Portion of anterior surface enlarged to show sinuous furrows.
Hamilton limestone, Milwaukee, Wis.

SANDALODUS CRASSUS, N. & W. (p. 204).

6. Complete tooth, showing posterior produced angle.
7. Tooth, usual form.
8. Tooth, showing crown much worn by use.
All natural size. Saint Louis limestone, Saint Louis, Mo.

CLADODUS CONCINNUS, Newb. (p. 170).

9, 10. Teeth of average size, posterior face; Fig. 10 showing central cone much worn.
Cleveland shale, Lorain County, Ohio.

HARPACANTHUS FIMBRIATUS, Stock. (p. 203).

11. Spine.
Saint Louis limestone, Alton, Ill.
11a. Spine, from drawing by Dr. R. H. Traquair.
Lower Carboniferous, Scotland.

PHYSONEMUS STELLATUS, Newb. (p. 200).

12. Spine, side view, natural size.
Saint Louis limestone, Greencastle, Ind.

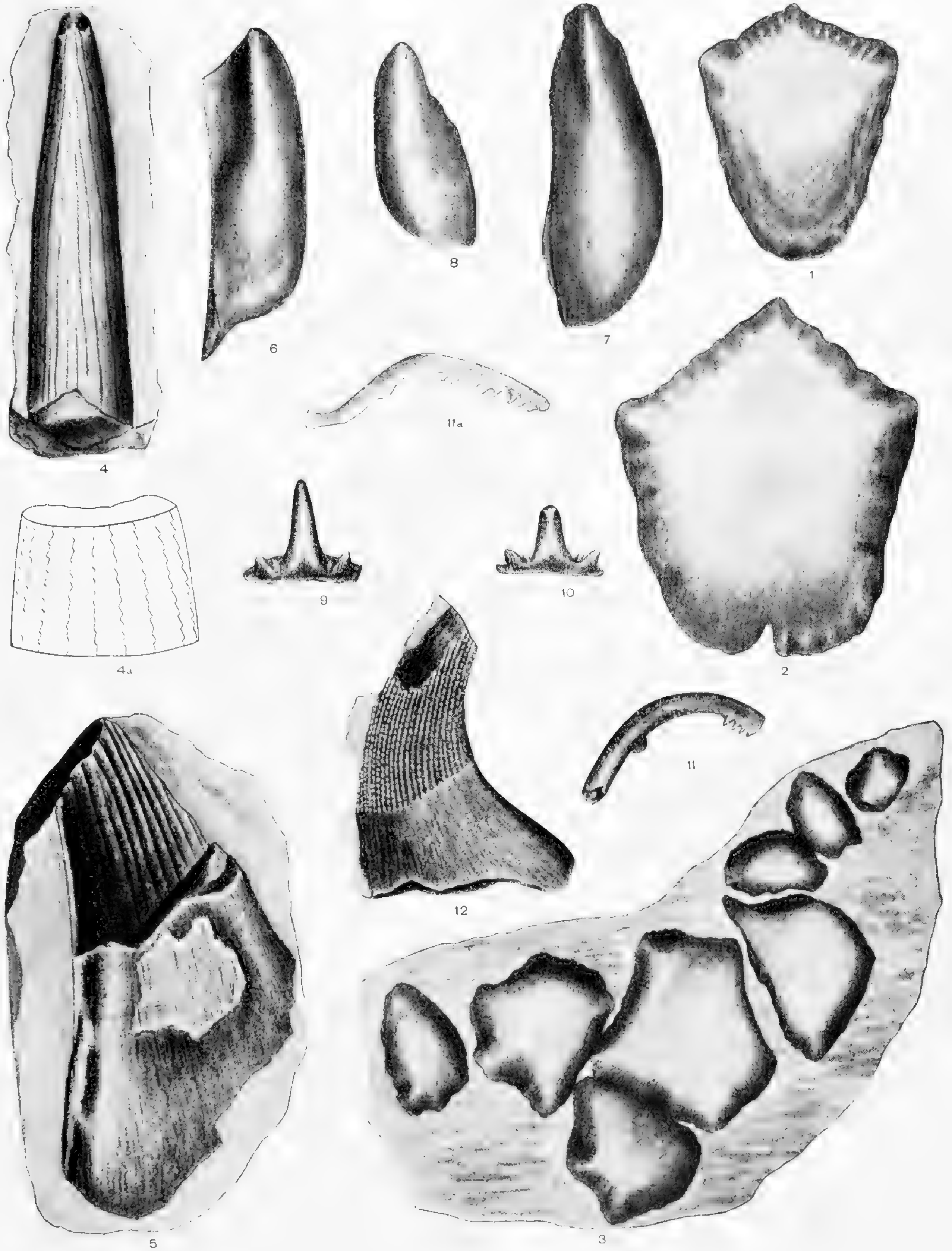

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PLATE XXII.

PLATE XXII.

ARCHÆOBATUS GIGAS, Newb. (p. 194).

FIG. 1. Anterior tooth, natural size.

2. Second tooth, natural size.

3. Outlines of the four teeth represented on Pls. XXII and XXIII, constituting part of marginal row with ends of an interior row, seen from above, reduced.

4. Profile of same series, reduced.

Saint Louis limestone, Greencastle, Ind.

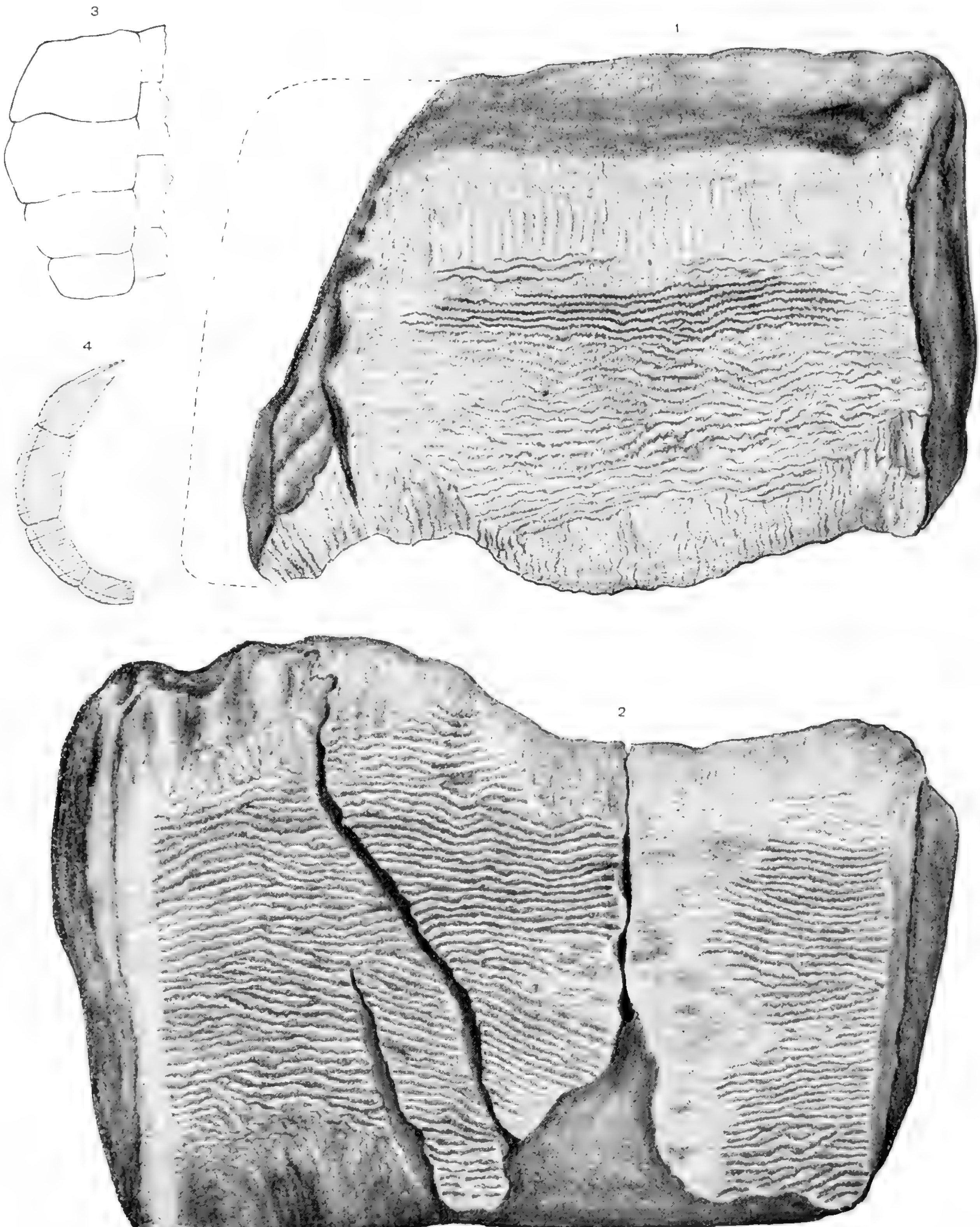

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PLATE XXIII.

PLATE XXIII.

ARCHÆOBATIS GIGAS, Newb. (p, 194).

FIGS. 1, 2. Third and fourth teeth of series represented on Pl. XXII.
3. End view of second tooth, natural size.
Greencastle, Ind.

CTENACANTHUS COMPRESSUS, Newb. (p. 168).

4. Spine, basal portion, natural size.
4a. Section at middle.
4b. Ornamentation enlarged.
Cleveland shale, Sheffield, Ohio.

GYRACANTHUS INORNATUS, Newb. (p. 177).

5. Spine, summit, much worn.
Cuyahoga shale (Waverly), Knox County, Ohio.

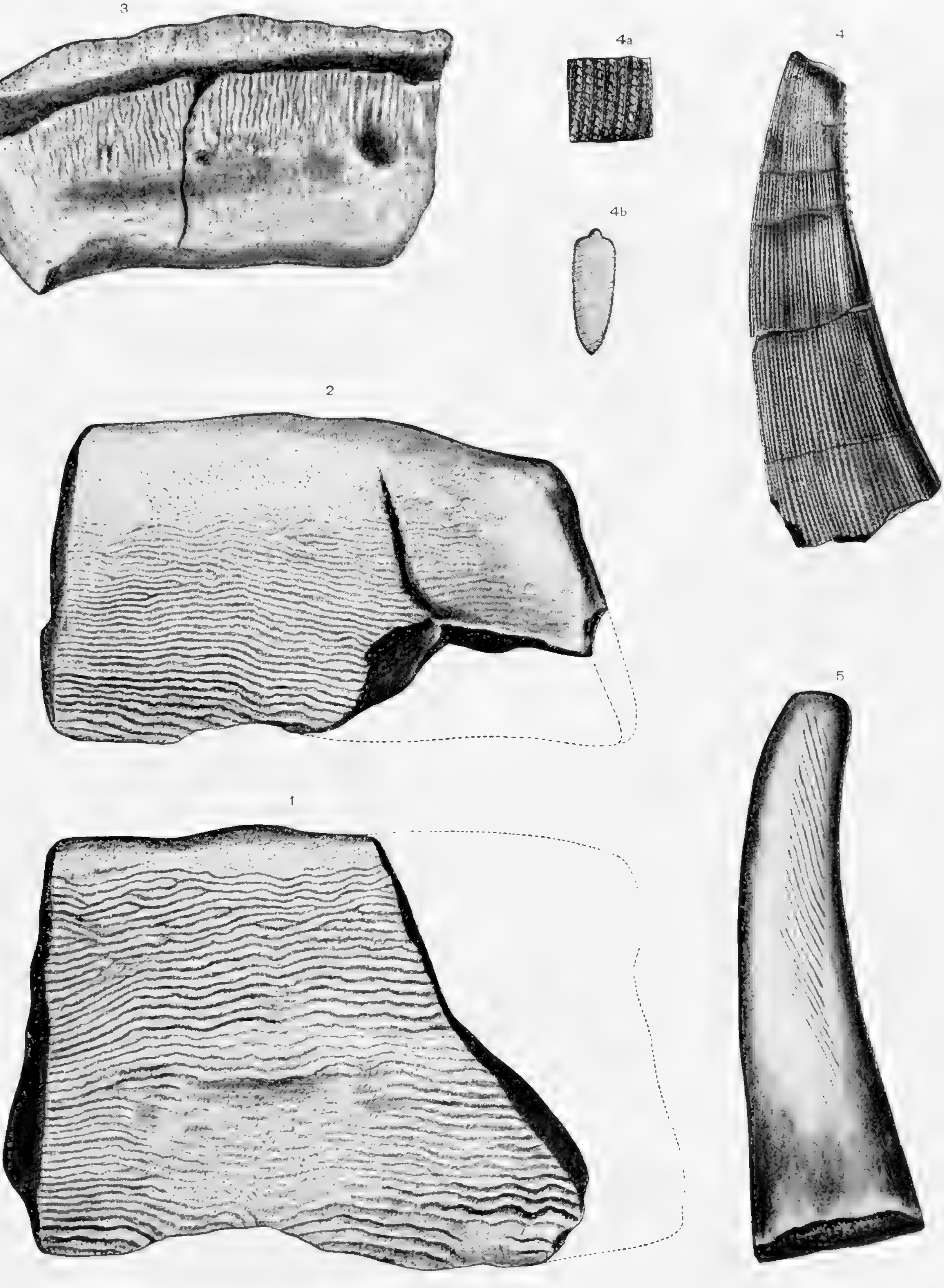

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PLATE XXIV.

PLATE XXIV.

STETHACANTHUS ALTONENSIS, St. J. & W. (sp.) (p. 198).

FIGS. 1, 2. Pectoral spine; views of opposite sides of same specimen, showing difference of breadth. Natural size. Saint Louis limestone, Alton, Ill.

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PLATE XXV.

PLATE XXV.

STETHACANTHUS TUMIDUS, Newb. (p. 198).

FIG. 1. Spine, natural size.
Berea grit, Berea, Ohio.

2. Spine with fin attached, side view, half natural size, slightly restored from impression in shale over grit.
Berea, Ohio.

2a. Spine No. 2 seen from above, half natural size.

CTENACANTHUS LITTONI, Newb. (p. 201).

3. Spine, base and part of ornamented surface, natural size.
Saint Louis limestone, Saint Louis, Mo.

ASTEROPTYCHIUS ELEGANS, Newb. (p. 176).

4. Spine, natural size.
Waverly sandstone, Grindstone City, Mich.

HOPLONCHUS PARVULUS, Newb. (p. 170).

5. Spine, natural size.
Cleveland shale, Bedford, Ohio.

ACONDYLACANTHUS OCCIDENTALIS, N. & W., sp. (p. 206).

6. Spine, natural size.
Saint Louis limestone, Alton, Ill.

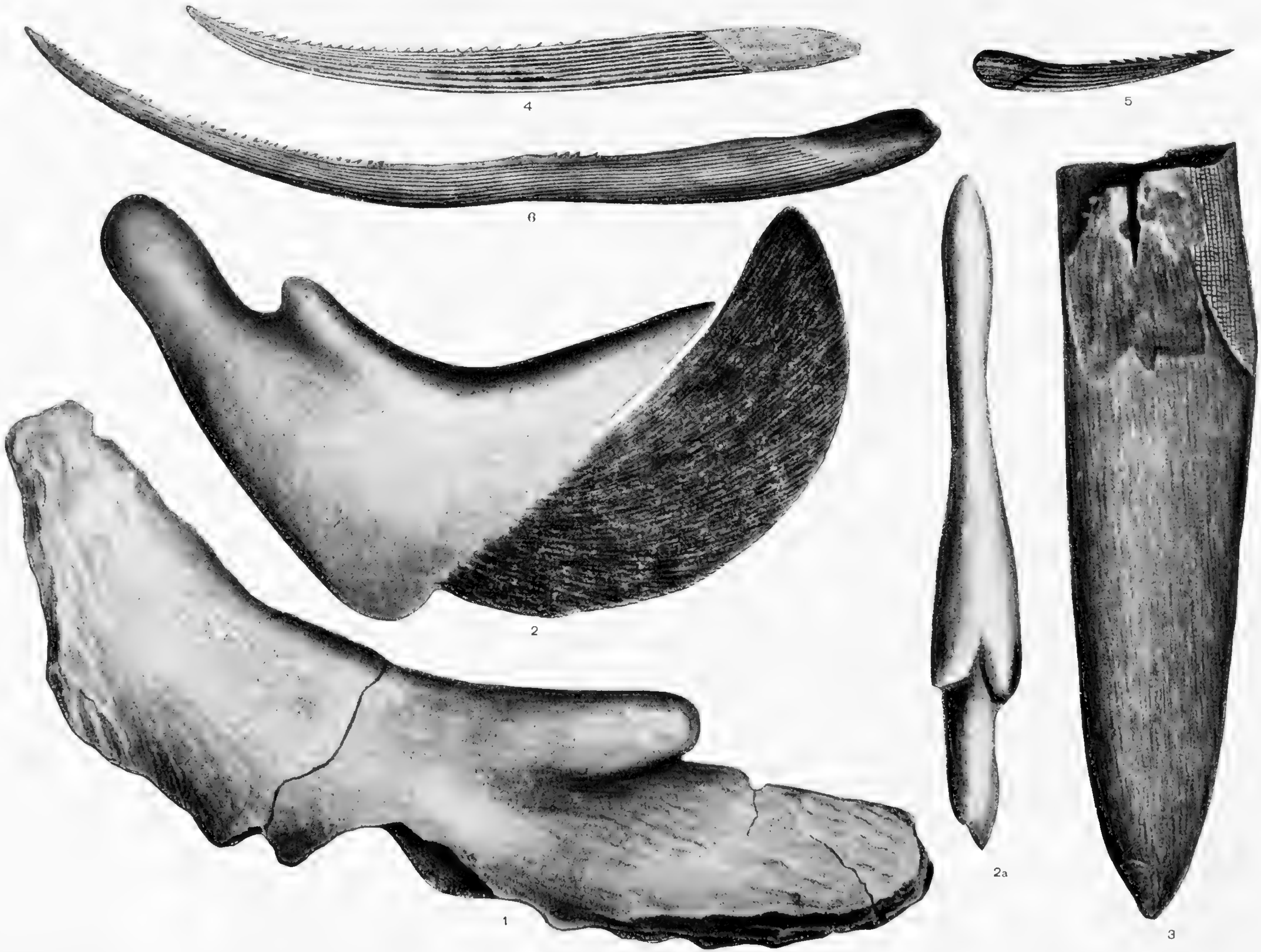

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PLATE XXVI.

PLATE XXVI.

CTENACANTHUS CYLINDRICUS, Newb. (p. 202).

FIG. 1. Spine, natural size; view of anterior face.
1^a, 1^b. Sections.
Keokuk group, Kentucky.

CTENACANTHUS CLARKII, Newb. (p. 168).

FIGS. 2, 3. Spine, natural size; views of opposite sides of same specimen.
2^a, 2^b. Sections.
Cleveland shale, Berea, Ohio.

CTENACANTHUS WRIGHTII, Newb. (p. 66).

FIG. 4. Spine, natural size; side view.
4^a. Section near summit.
4^b. Ornamentation enlarged.
Hamilton group, Yates County, N. Y.

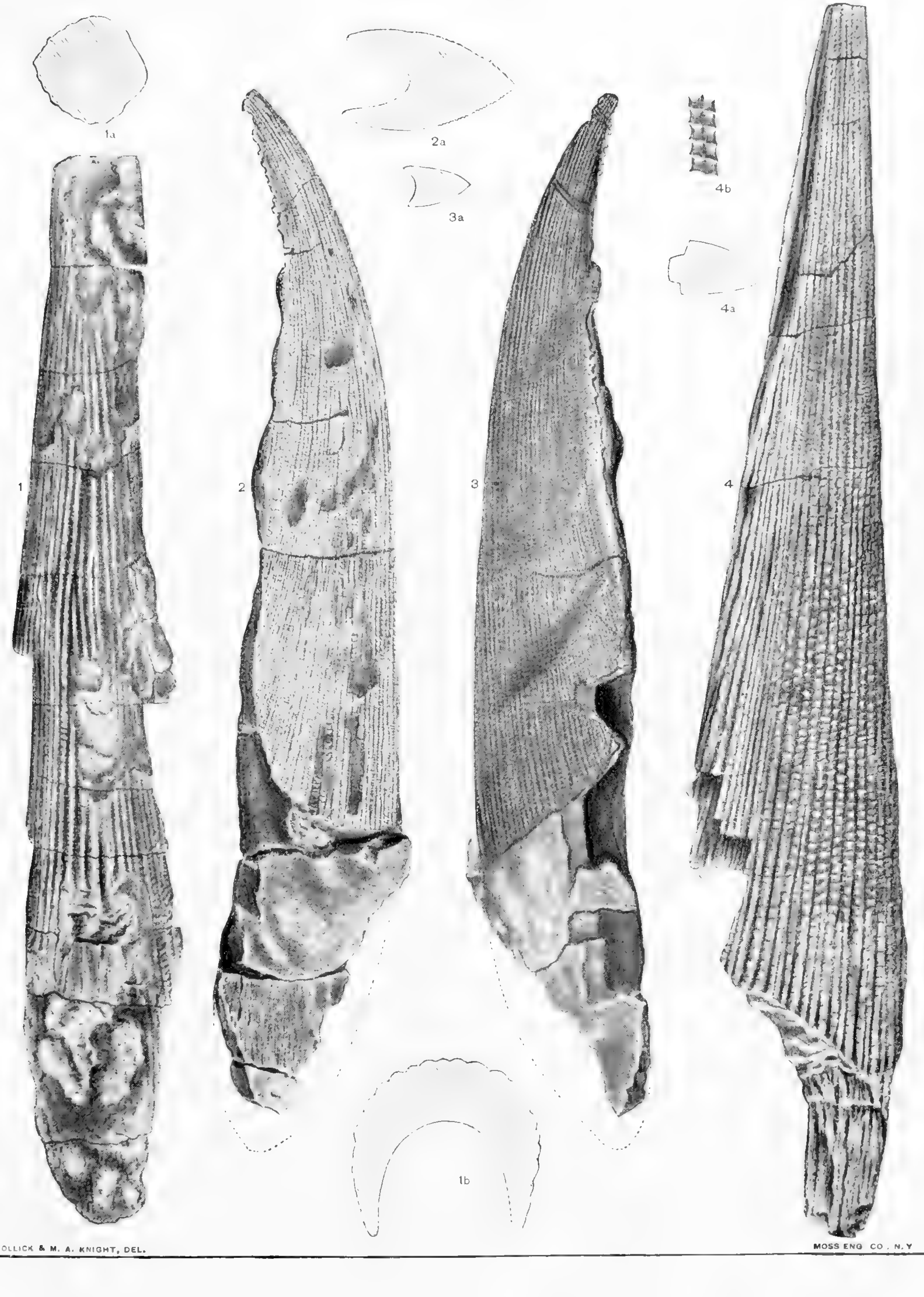

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PLATE XXVII.

PLATE XXVII.

PETRODUS BUTTERSII, Newb.

FIG. 1. Dermal tubercles.

2. Group of united tubercles. Coal Measures, Carlinville, Ill.

CLADODUS CONCINNUS, Newb. (p. 70).

3, 4. Teeth of small form, with two and four lateral denticles. Cleveland shale, Sheffield, Ohio.

CLADODUS TERRELLI, Newb. (p. 170).

5, 6, 6a, 7. Teeth. Cleveland shale, Sheffield, Ohio.

CLADODUS TUMIDUS, Newb. (p. 172).

8, 9. Tooth, posterior face and base. Cleveland shale, Sheffield, Ohio.

CLADODUS ROMINGERI, Newb. (p. 177).

10. Tooth, posterior face. Waverley, Grindstone City, Mich.

GONIODUS HERTZERI, Newb. (p. 69).

11–15. Teeth of various forms. Huron shale, Delaware, Ohio.

CALLOGNATHUS SERRATUS, Newb. (p. 70).

16, 17. Dentary bone. Cleveland shale, Lorain County, Ohio.

CALLOGNATHUS REGULARIS, Newb. (p. 70).

18. Dentary bone. Huron shale, Delaware, Ohio.

CTENODUS (DIPTERUS) NELSONI, Newb. (p. 89).

19, 20. Teeth. Chemung group, Warren, Pa.

CTENODUS (DIPTERUS) FLABELLIFORMIS, Newb. (p. 90).

21, 21a. Teeth, large and small forms. Chemung group, Warren, Pa.

CTENODUS (DIPTERUS) LEVIS, Newb. (p. 90).

22, 23. Teeth. Chemung group, Warren, Pa.

CTENODUS (DIPTERUS) QUADRATUS, Newb.

24, 25. Teeth. Chemung group, Warren, Pa.

CTENODUS (DIPTERUS) MINUTUS, Newb. (p. 91).

26. Tooth. Chemung group, Warren, Pa.

PHŒBODUS POLITUS, Newb. (p. 173).

27–28a. Tooth; posterior face and base. Cleveland shale, Lorain County, Ohio.

ORODUS RAMOSUS, Ag. (p. .05).

29. Tooth. Waverly, Grindstone City, Mich.

CTENODUS WAGNERI, Newb. (p. 172).

30. Tooth. Cleveland shale, Cleveland, Ohio.

CTENODUS SERRATUS, Newb. (p. 226).

31, 31a. Tooth; upper surface and profile. Coal Measures, Linton, Ohio.

DIPTERUS (CTENODUS) SHERWOODI, Newb. (p. 118).

32, 32b. Lower tooth, upper surface and profile. Catskill group, Tioga County, Pa.

DIPTERUS (CTENODUS) RADIATUS, Newb. (p.119).

33. Tooth. Catskill group, Tioga County, Pa.

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PLATE XXVIII.

PLATE XXVIII.

RHYNCHODUS SECANS, Newb. (p. 47).

FIG. 1. Left maxillary tooth, showing inside of cutting edge.
1a. Section.
2, 3. Upper and lower beak-teeth in their relative positions.

RHYNCHODUS CRASSUS, Newb. (p. 49).

4. Left inferior tooth, showing inside and triturating surface. Figs. 1–4, natural size.
Corniferous limestone, Delaware, Ohio.

CTENACANTHUS VETUSTUS, Newb.

5, 5d. Side view and sections.
Cleveland shale, Sheffield, Ohio.

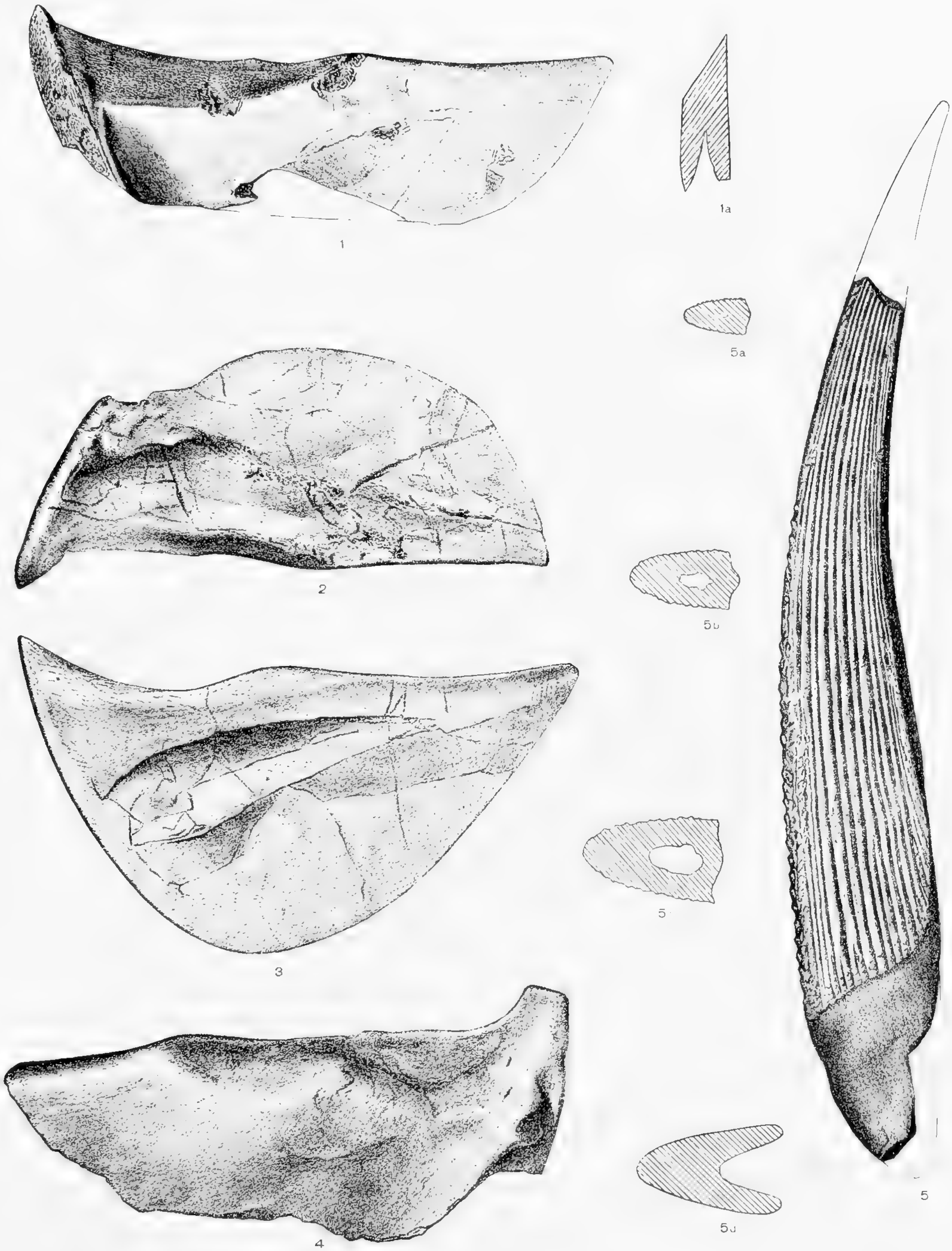

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PLATE XXIX.

PLATE XXIX.

RHYNCHODUS EXCAVATUS, Newb. (p. 50).

FIG. 1. Left lower tooth, natural size.
Hamilton group, Brown Deer, Wis.
1ª. Section.

RHYNCHODUS FRANGENS, Newb. (p. 48).

2. Lower left dental plate, outside view, natural size.
2ª. Triturating face of Fig. 2.
Corniferous limestone, Delaware, Ohio.
3. Solid triturating angle of right lower dental plate, inside view, natural size.
Corniferous limestone, Kelley's Island, Lake Erie.

MACHÆRACANTHUS MAJOR, Newb. (p. 39).

4. Short and robust pectoral spine, upper side, natural size.
4ª. Section of same.
Corniferous limestone, Delaware, Ohio.

MACHÆRACANTHUS SULCATUS, Newb. (p. 40).

5. Pectoral spine, under side, natural size.
5ª. Section of same.
Corniferous limestone, Canada.

MACHÆRACANTHUS PERACUTUS, Newb. (p. 38).

6. Pectoral spine, upper surface.
6ª. Section.
Corniferous limestone, Delaware, Ohio.

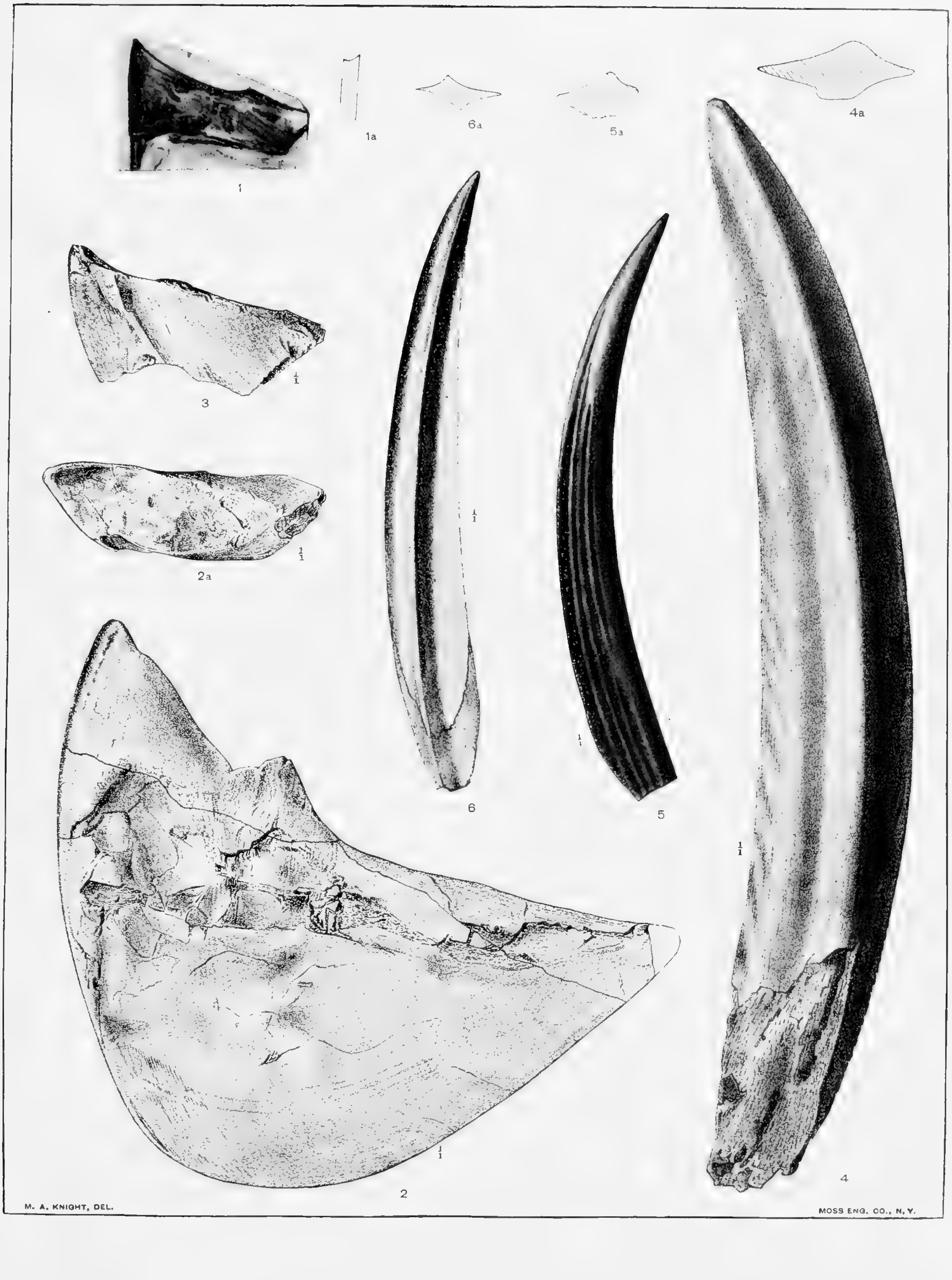

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PLATE XXX.

PLATE XXX.

ASTEROSTEUS STENOCEPHALUS, Newb. (p. 44).

FIG. 1. Cranium seen from above, outline completed from another specimen, natural size.
Corniferous limestone, Sandusky, Ohio.

COCCOSTEUS OCCIDENTALIS, Newb. (p. 52).

2. Dorsomedian plate.
2a. Ventromedian plate, inside.

COCCOSTEUS DECIPIENS, Ag.

3. Dorsomedian plate.
4, 4a. Ventromedian plate, outside and inside views.
Devonian limestone, Scotland.

LIOGNATHUS SPATULATUS, Newb. (p. 52).

5. Mandible.

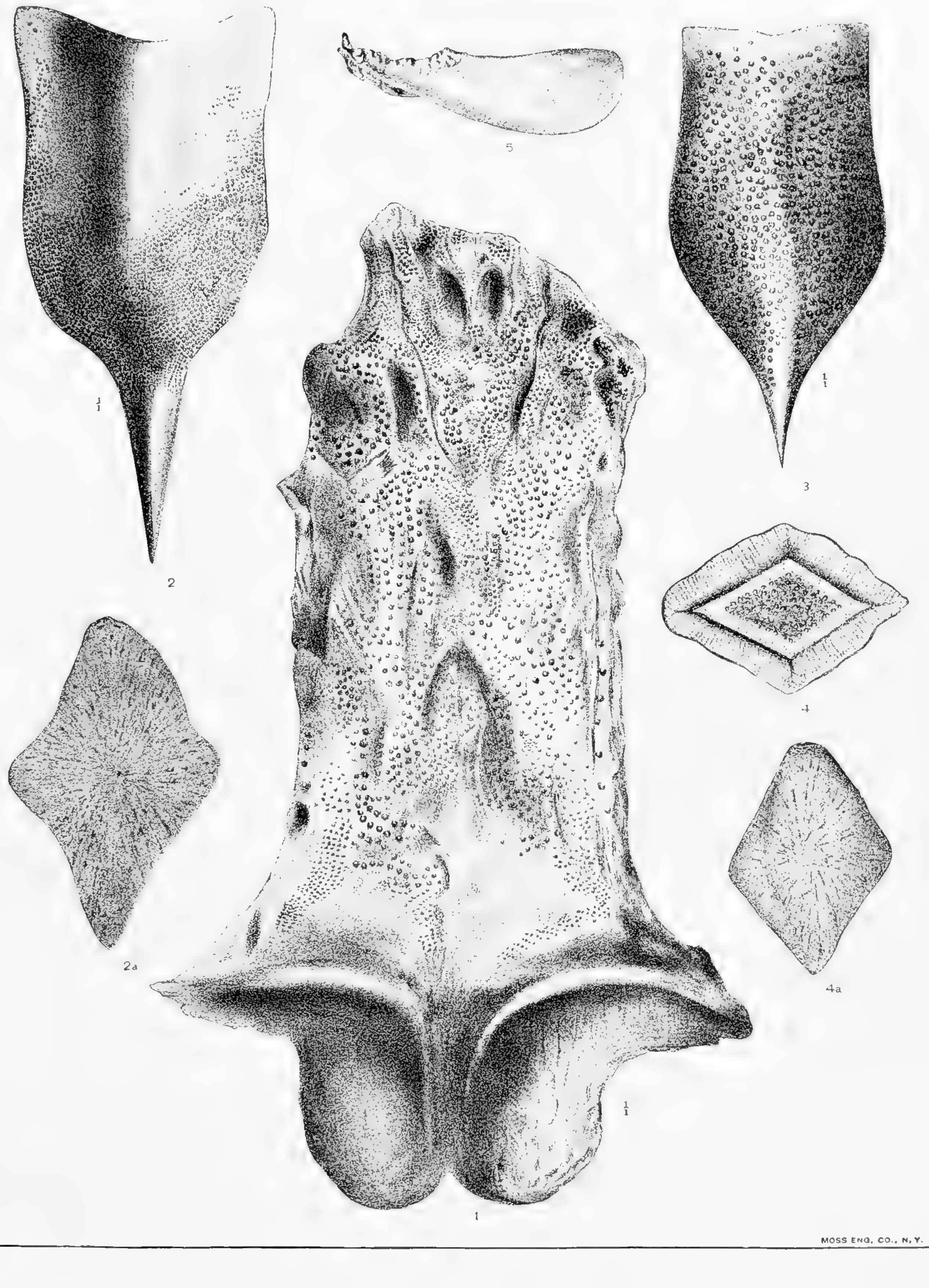
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PLATE XXXI.

PLATE XXXI.

ACANTHASPIS ARMATUS, Newb. (p. 36).

FIGS. 1, 2, 3. Cephalic plates, bearing spine.
2ª. Ornamentation, enlarged.
4. Cephalic plate, inside, natural size.
Corniferous limestone, Delaware, Ohio.

ACANTHOLEPIS PUSTULOSUS, Newb. (p. 33).

5, 5ª. Two lateral scutes in natural position, showing outer surface, natural size.
5ᵇ. Four scutes in relative position, much reduced.
Corniferous limestone, Sandusky, Ohio.

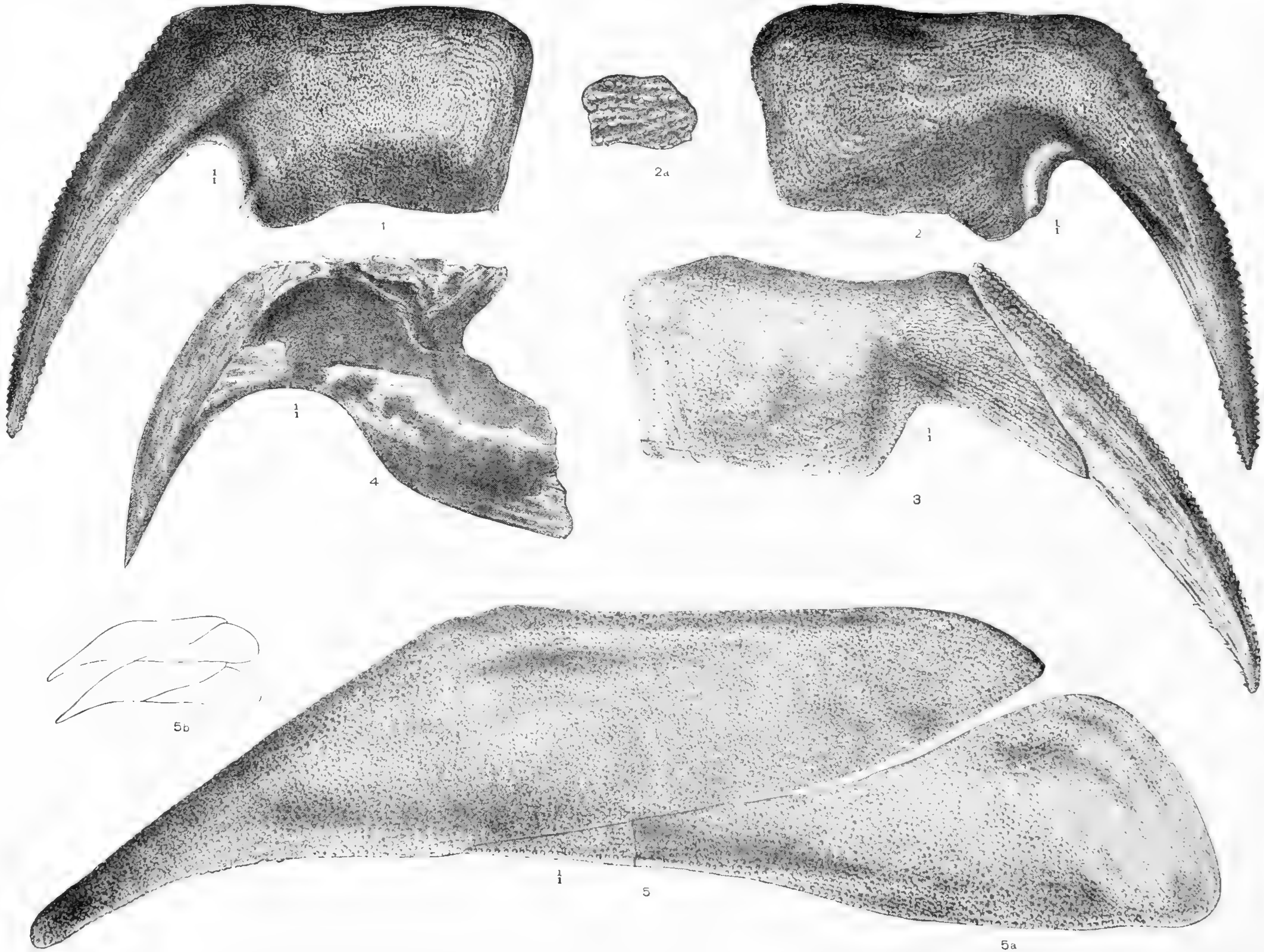

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PLATE XXXII.

PLATE XXXII.

DINICHTHYS TERRELLI, Newb.

FIG. 1. Premaxillary tooth, natural size. Cleveland shale, Sheffield, Ohio.

DINICHTHYS HERTZERI, Newb. (p. 64).

2. Premaxillary tooth, natural size. Huron shale, Delaware, Ohio.

DINICHTHYS TUBERCULATUS, Newb. (p. 98).

3. Supra-scapula, natural size. Chemung group, Warren, Pa.

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PLATE XXXIII.

PLATE XXXIII.

DINICHTHYS TERRELLI, Newb.

Inside view of anterior portion of right mandible, very large and much worn by use; a fragment broken off by violence and found buried in the soft carbonaceous mud which once formed the sea bottom, and is now the Cleveland shale, natural size.

Sheffield, Lorain County, Ohio.

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PLATE XXXIV.

PLATE XXXIV.

GONATODUS BRAINERDI, Thomas (sp.).

FIG. 1. Entire fish, side view, natural size.
Berea grit, Independence, Cuyahoga County, Ohio.

2. Entire fish, showing dorsal surface, natural size.
Berea grit, Chagrin Falls, Ohio.

ONYCHODUS SIGMOIDES, Newb. (p. 56).

3. Maxillary, natural size.
Corniferous limestone, Delaware, Ohio.

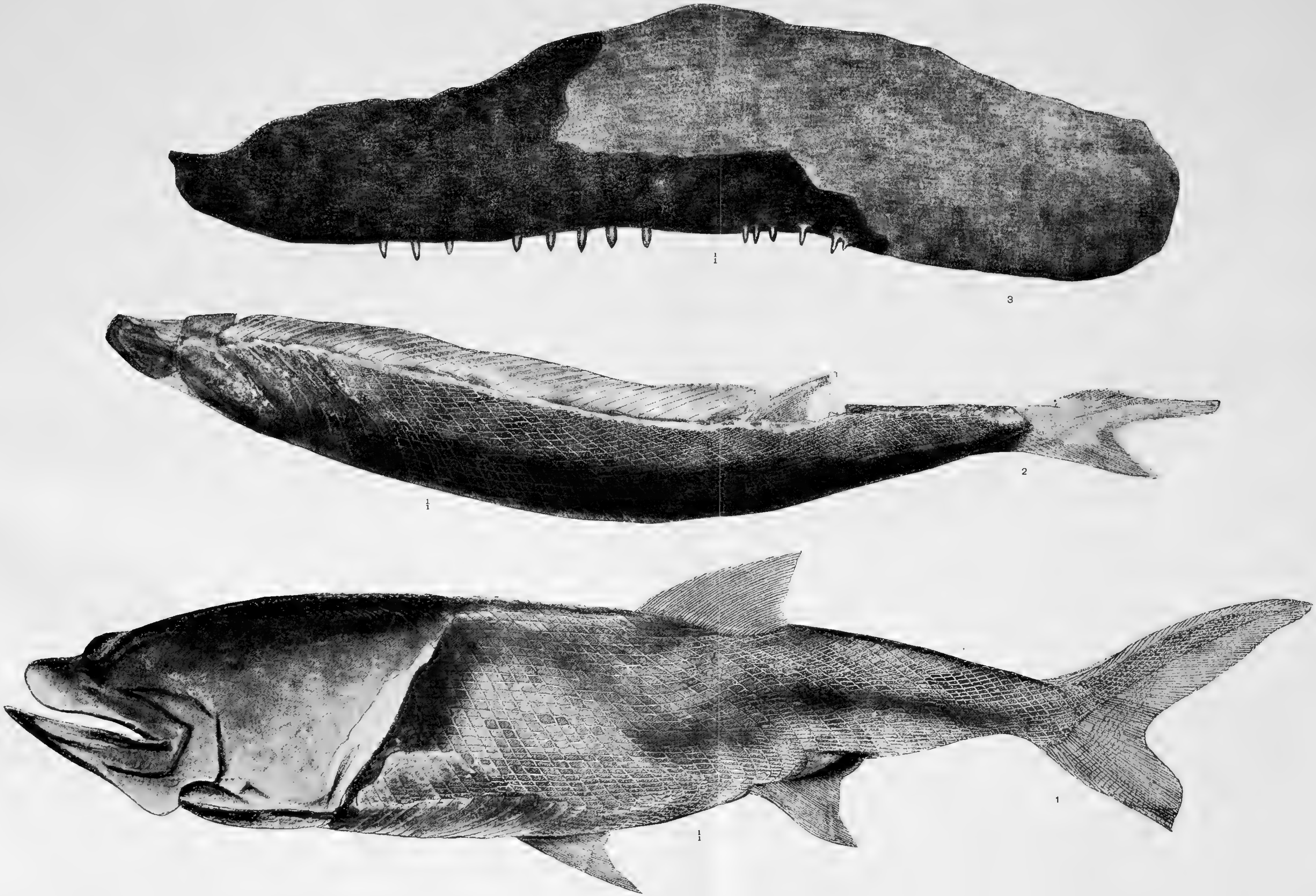

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PLATE XXXV.

PLATE XXXV.

Cœlosteus ferox, Newb. (p. 190).

Fig. 1. Dentary bone, inside.
2. Dentary bone, outside.
3. Dentary bone, upper side.
4. Weathered section of tooth, showing plications at base.
All natural size. Saint Louis limestone, Alton, Ill.

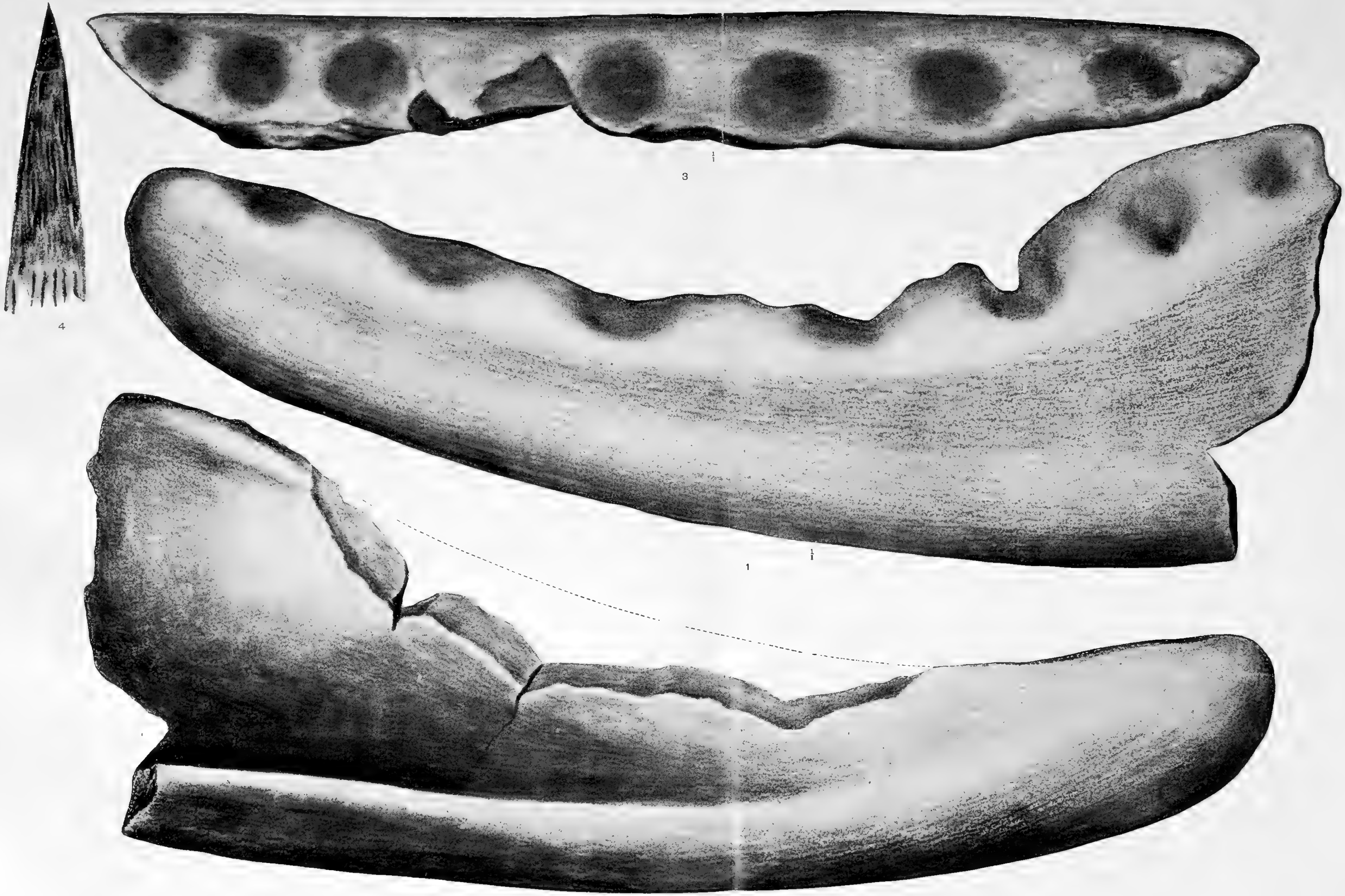

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PLATE XXXVI.

PLATE XXXVI.

ONYCHODUS SIGMOIDES, Newb. (p. 56).

FIG. 1. Dentary bone, inner surface, natural size.

1^a 1^b. Scales, inner and outer surfaces.

2. Dentary bone, outer surface, showing crest of intermandibular teeth in position, natural size.

2^a. Ornamentation of outer surface, enlarged.

3. Intermandibular arch of small individual.

4. Dentary bone of small individual, outside.

4^a. Cross-section of 4.

All from Corniferous limestone, Delaware, Ohio.

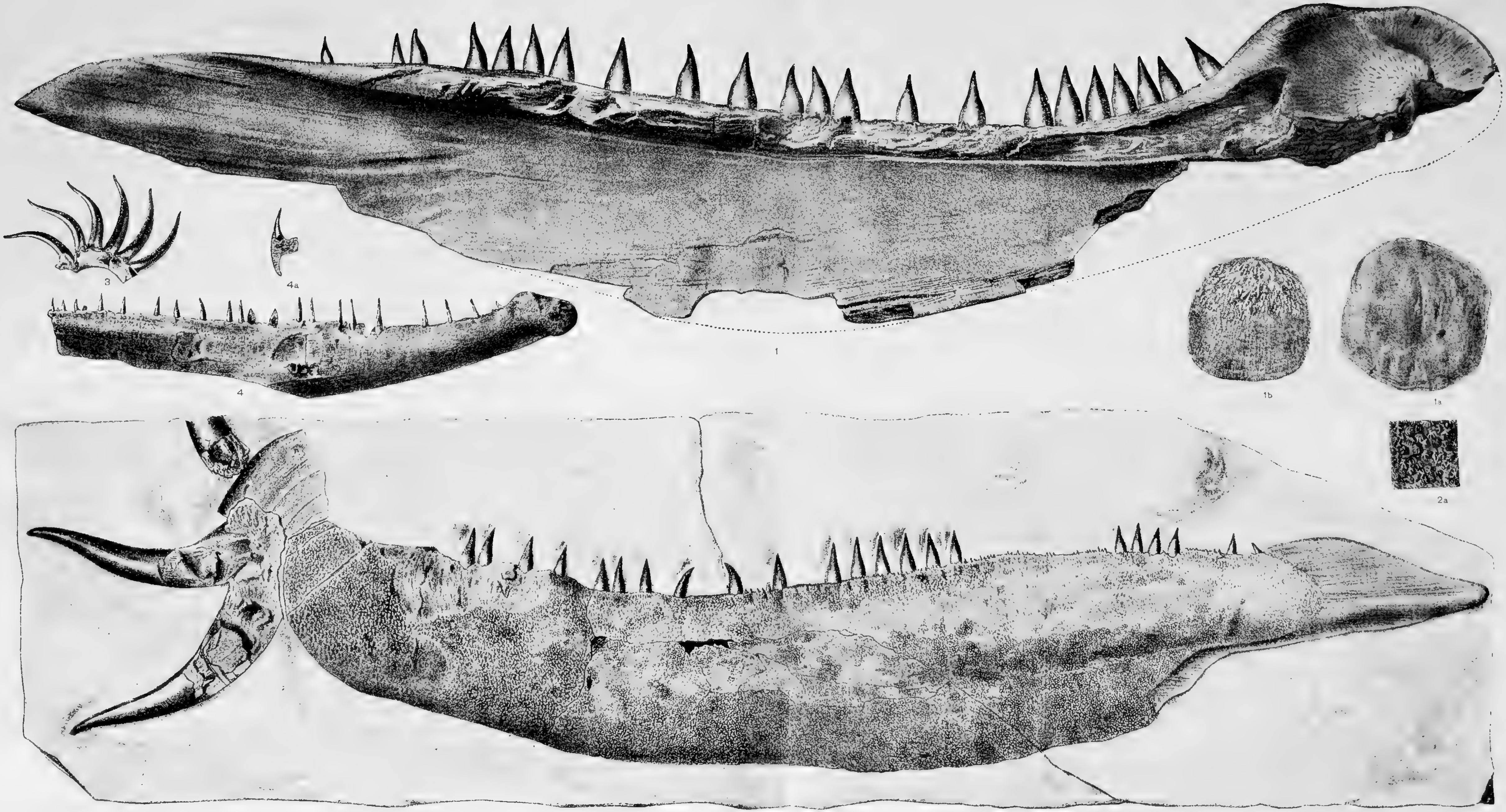

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PLATE XXXVII.

PLATE XXXVII.

ONYCHODUS SIGMOIDES, Newb. (p. 56).

FIGS. 1, 2. Jugular plates.
3. Entire frontal plate.
4. Anterior half of two frontals, in position.
5. Supra-temporal plate.
6. Operculum, inside.
7. Clavicle, inside.
8. Parietal ?, inside.
9. Suboperculum ?, outside.
10. Suboperculum ?, inside.
11. Operculum of small individual, outside.

All figures, except 11, half natural size.
Corniferous limestone, Delaware, Ohio.

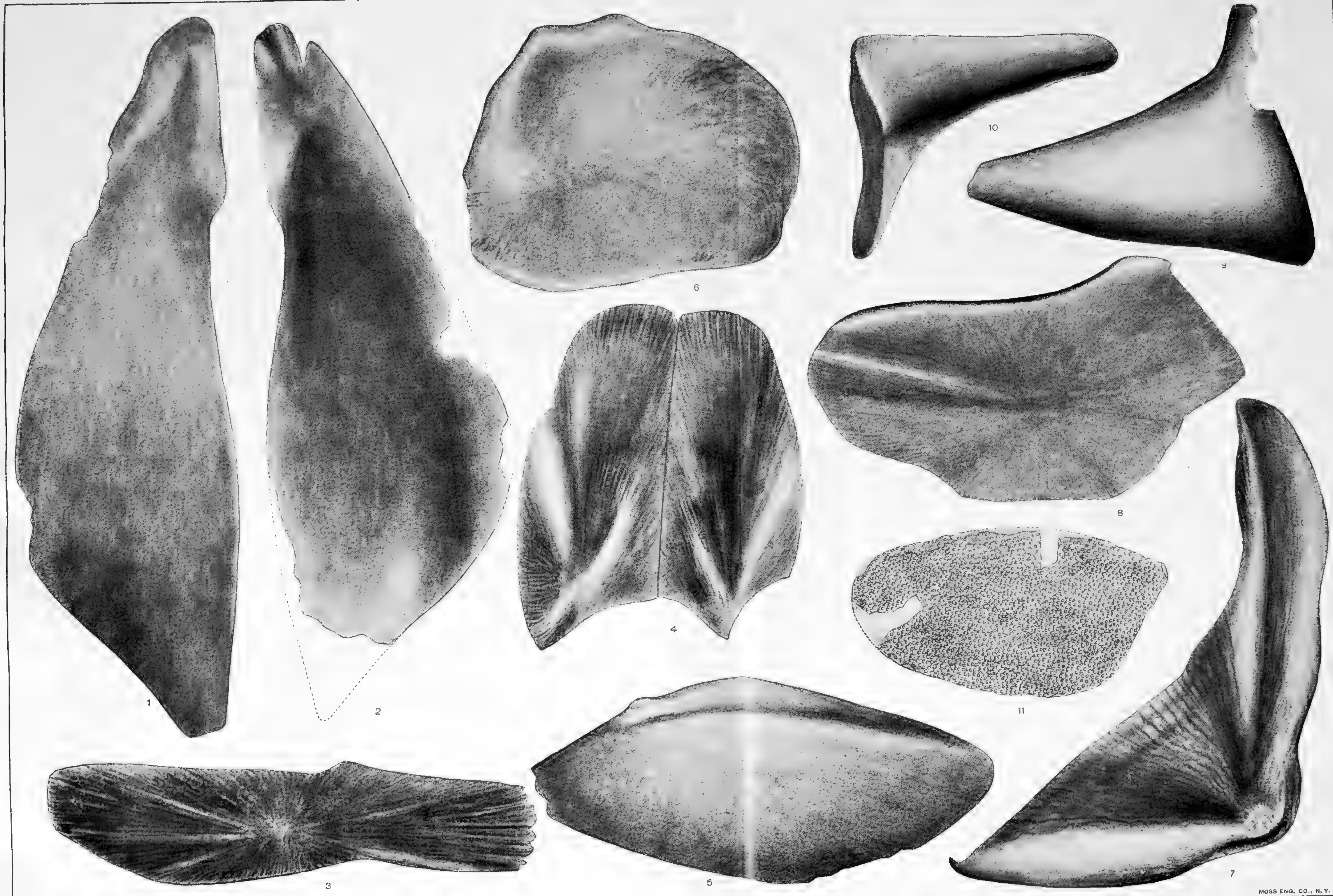

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PLATE XXXVIII.

PLATE XXXVIII.

MACROPETALICHTHYS SULLIVANTI, Newb. (p. 27).

FIG. 1. Inside of cranium, natural size.
2. Side view of cranium, outside.
2a. Ornamentation, enlarged.

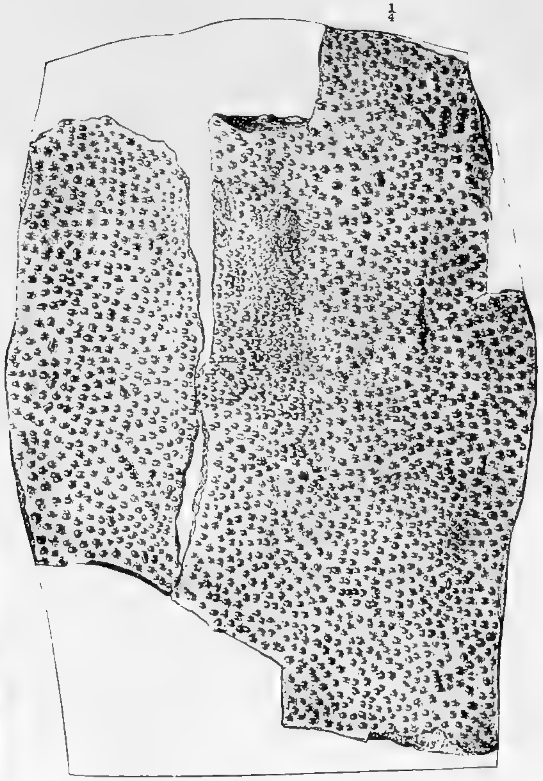
ASPIDICHTHYS CLAVATUS, Newb. (p. 73).

3. Dorsomedian shield, one-fourth natural size, linear.
4. Portion of dorsal shield, drawn natural size to show tuberculation.

$\frac{1}{2}$

1

$\frac{1}{4}$



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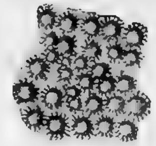

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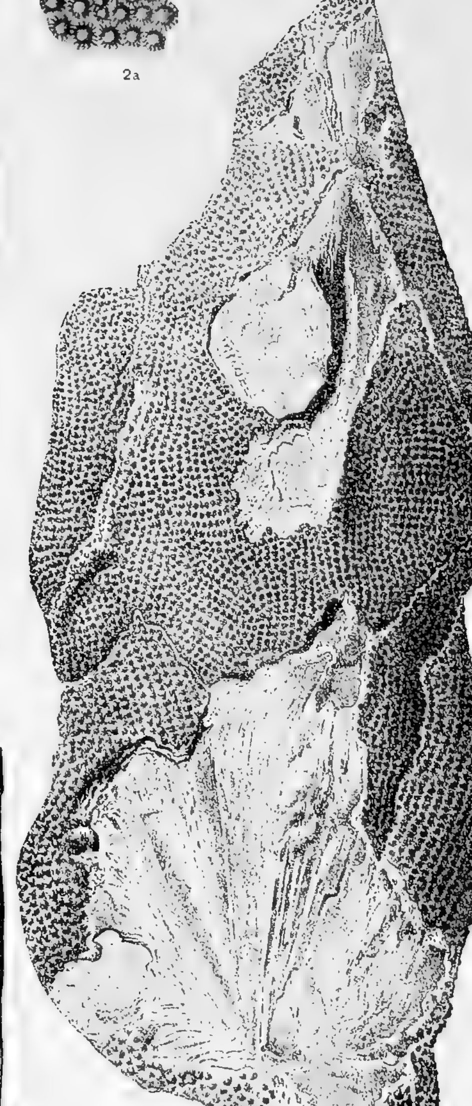

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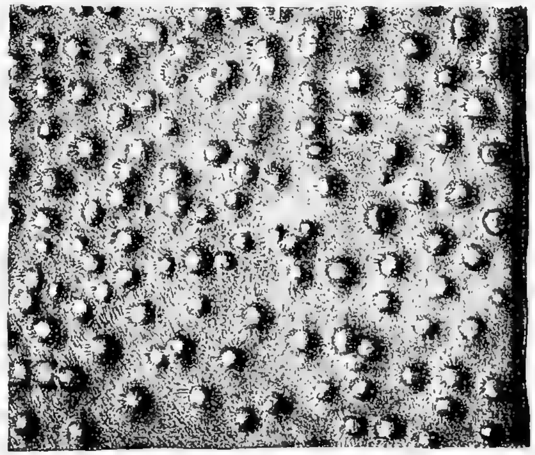

4 $\frac{1}{2}$

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PLATE XXXIX.

PLATE XXXIX.

EDESTUS MINOR, Newb. (p. 225).

FIG. 1. Doral spine, side view, natural size.
1ª. Section, natural size.
Coal Measures, Park County, Ind.

EDESTUS HEINRICHSI, N. & W. (p. 225).

2. Doral spine, side view, natural size.
2ª. Young spine with single denticle.
2ᵇ. Sheathing segment carrying denticle.
Coal Measures, Vermillion County, Ind., and Belleville, Ill.

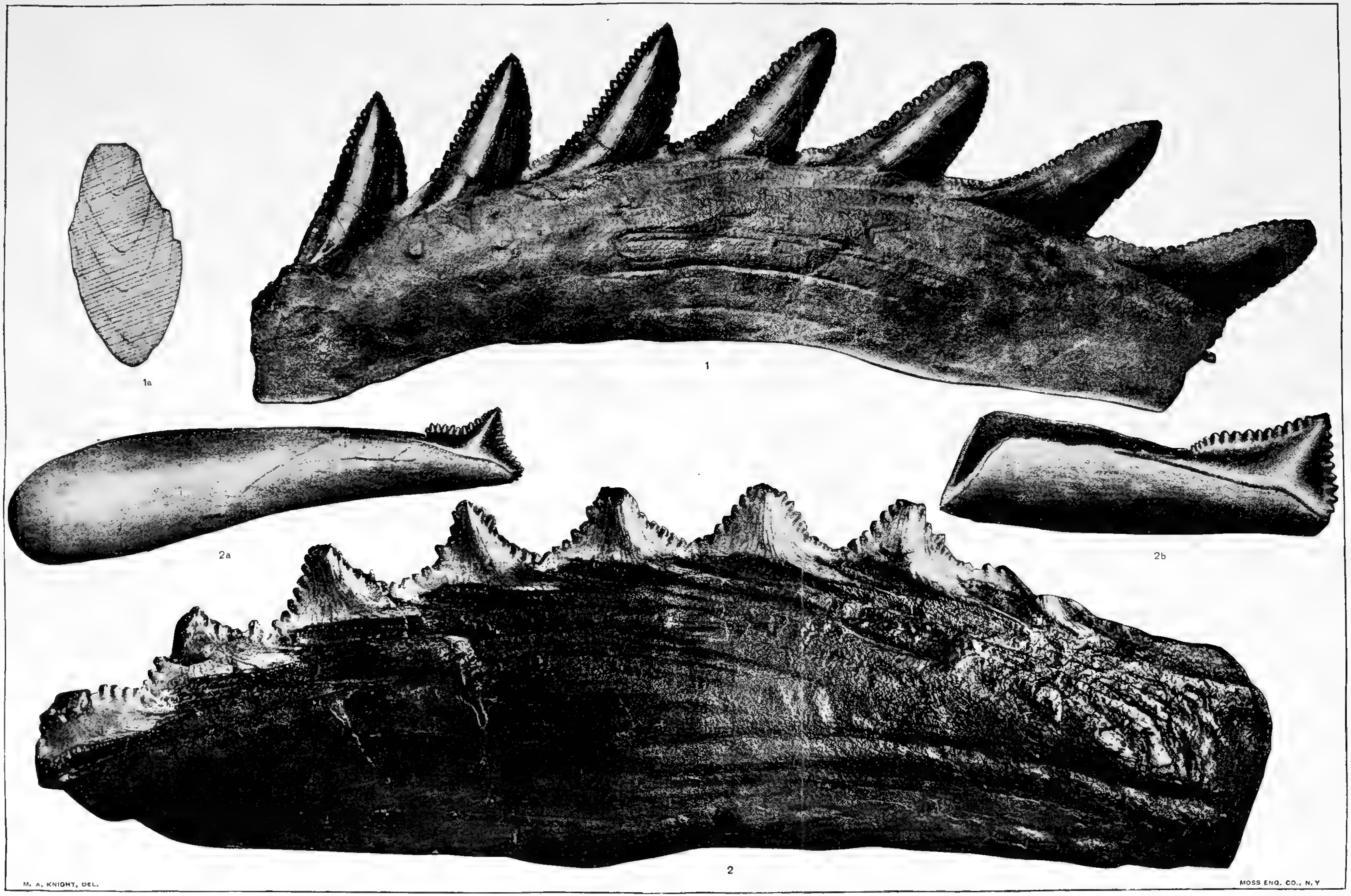

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PLATE XL.

PLATE XL.

EDESTUS GIGANTEUS, Newb. (p. 225).

Basal half of spine, side view, natural size.
Coal Measures, Decatur, Ill.

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PLATE XLI.

PLATE XLI.

DINICHTHYS ? PRECURSOR, Newb. (p. 51).

Dorsomedian shield, natural size.
Corniferous limestone, Sylvania, Ohio.

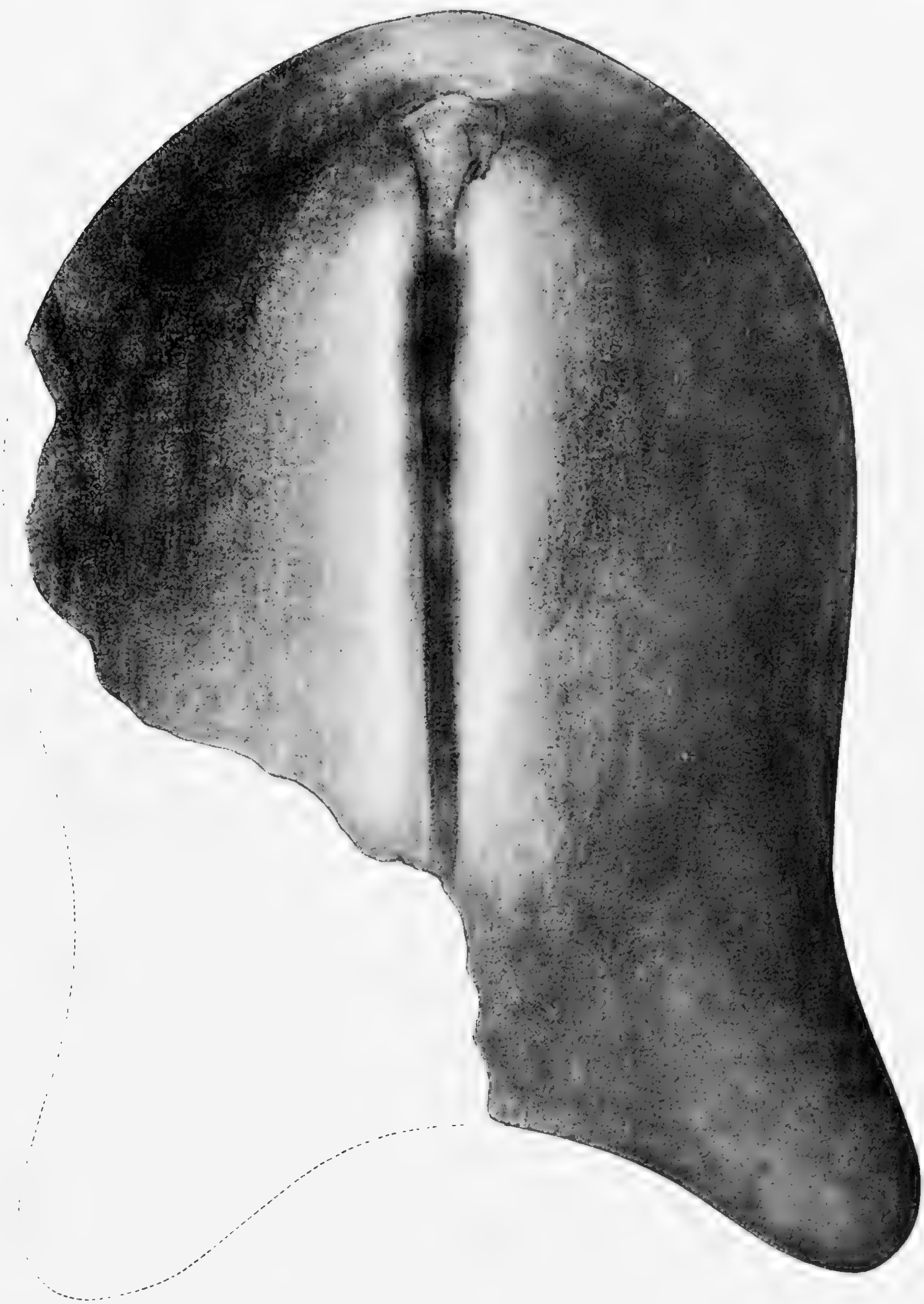

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PLATE XLII.

PLATE XLII.

TRACHOSTEUS CLARKII, Newb. (p. 167).

FIG. 1. Post-dorsolateral plate ?, half natural size.
2. Eye-orbit with ring of sclerotic plates, inner surface, natural size.
3. Mandibles, right and left broken at anterior extremity, natural size.
4. Premaxillary ?, natural size.
5. Maxillary ?, natural size.
6. Tuberculation where least crowded, showing stellation of bases of tubercles.
7. Tubercles where most crowded, enlarged.

Cleveland shale, Berea, Ohio.

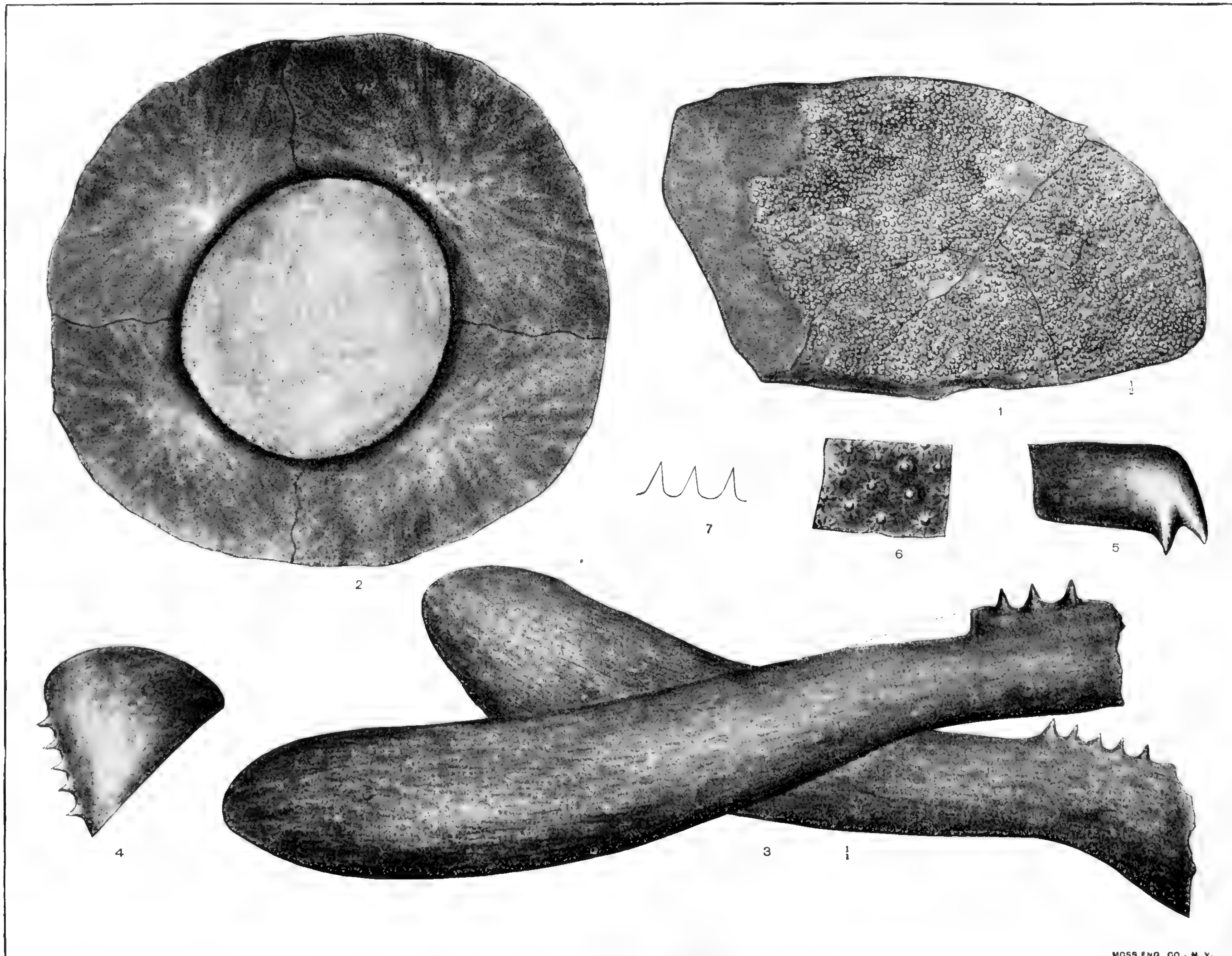
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PLATE XLIII.

PLATE XLIII.

RHIZODUS ANCEPS, Newb. (p. 191).

FIG. 1. Anterior ha.f of mandible, natural size. Saint Louis limestone, Alton, Ill.

DINICHTHYS TERRELLI, Newb.

2. Pineal fontanelle, inside, natural size. Cleveland shale, Sheffield, Ohio.

DINICHTHYS MINOR ?, Newb. (p. 149).

3. Pineal fontanelle, natural size. Cleveland shale, Sheffield, Ohio.

TITANICHTHYS CLARKII, Newb. (p. 133).

4. Tooth ?, side view.
4a. Section, natural size.
Cleveland shale, Berea, Ohio.

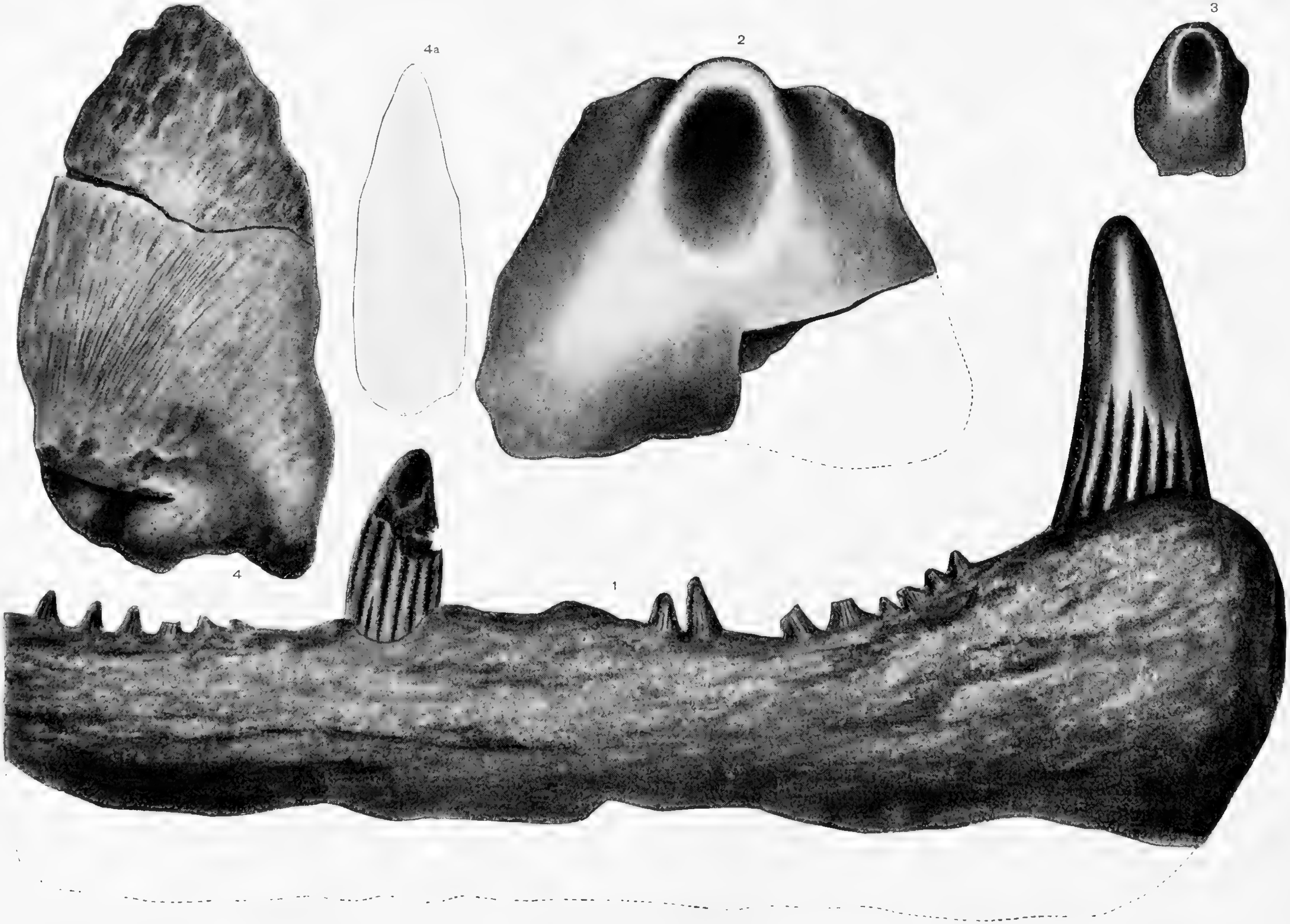

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PLATE XLIV.

PLATE XLIV.

CLADODUS KEPLERI, Newb. (p. 103).

FIG. 1. Under side of anterior half of body, showing head with eye-orbits, mandibles with teeth, opercular shields, branchial arches, base of dorsal spine, and pectoral fins; about one-fourth natural size.

2. Tooth, natural size.

3. Eye-orbit, natural size, somewhat distorted.

From calcareous lenticular concretion in Cleveland shale, near Brooklyn, Cuyahoga County, Ohio. Collected by Rev. William Kepler. Original in the Geological Museum of the School of Mines, Columbia College, New York.

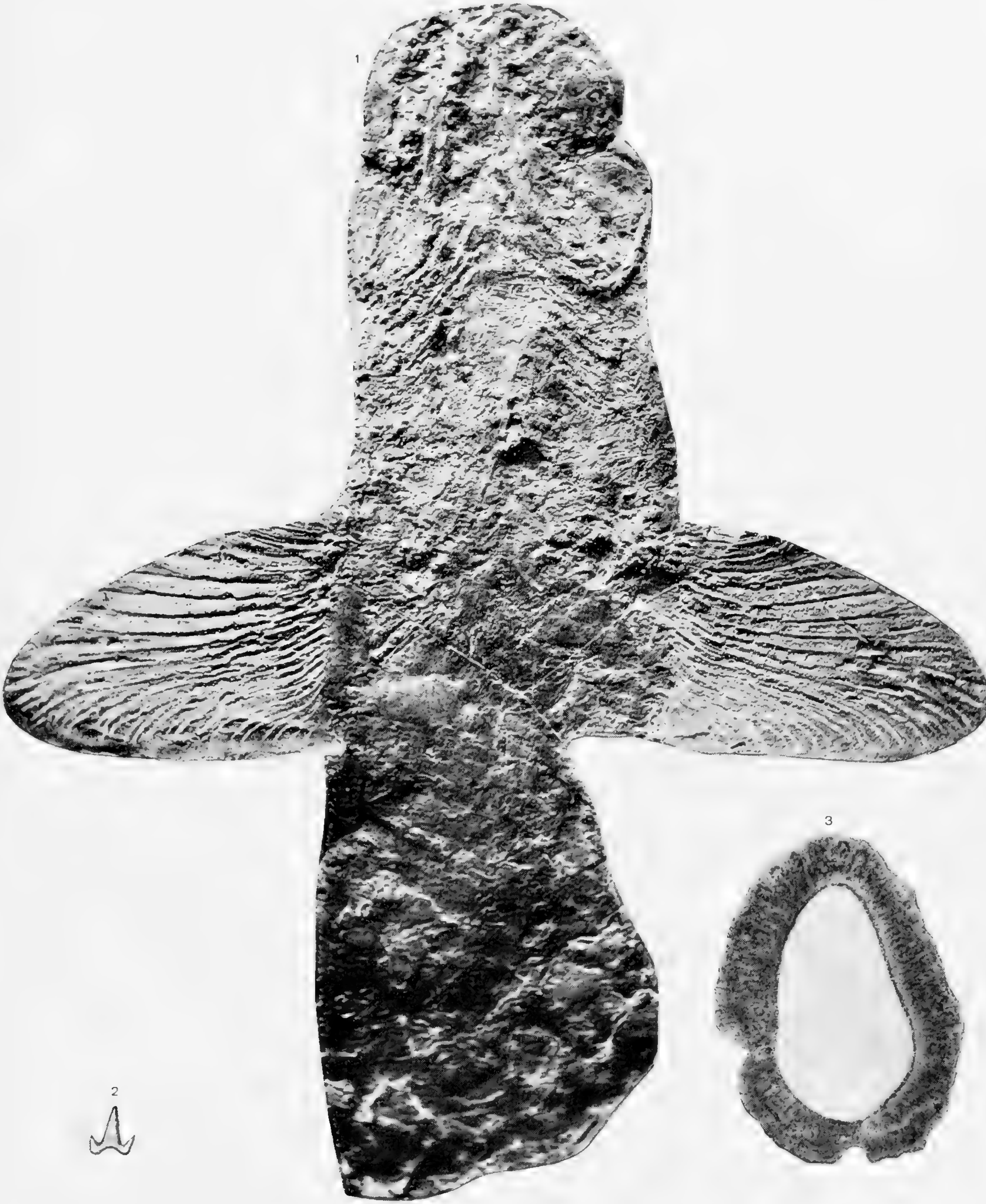

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PLATE XLV.

PLATE XLV.

Cladodus Kepleri, Newb. (p. 103).

Under side of anterior half of body; one-fourth natural size, linear.
Counterpart of specimen represented on Pl. XLIV.
Cleveland shale, Brooklyn, Ohio.

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PLATE XLVI.

PLATE XLVI.

CLADODUS FYLERI, Newb.

Entire fish, natural size; showing *a*, eye orbits; *b*, opercular shields, pectoral fins; *c*, dorsal spine?; *d*, scale-like dermal plates; *e*, ventral fins; *f*, edge of caudal fin.

Cleveland shale, near Brooklyn, Cuyahoga County, Ohio. Collected by Dr. William Clark. Original in the cabinet of the School of Mines of Columbia College, New York.


a
b
d
e
f

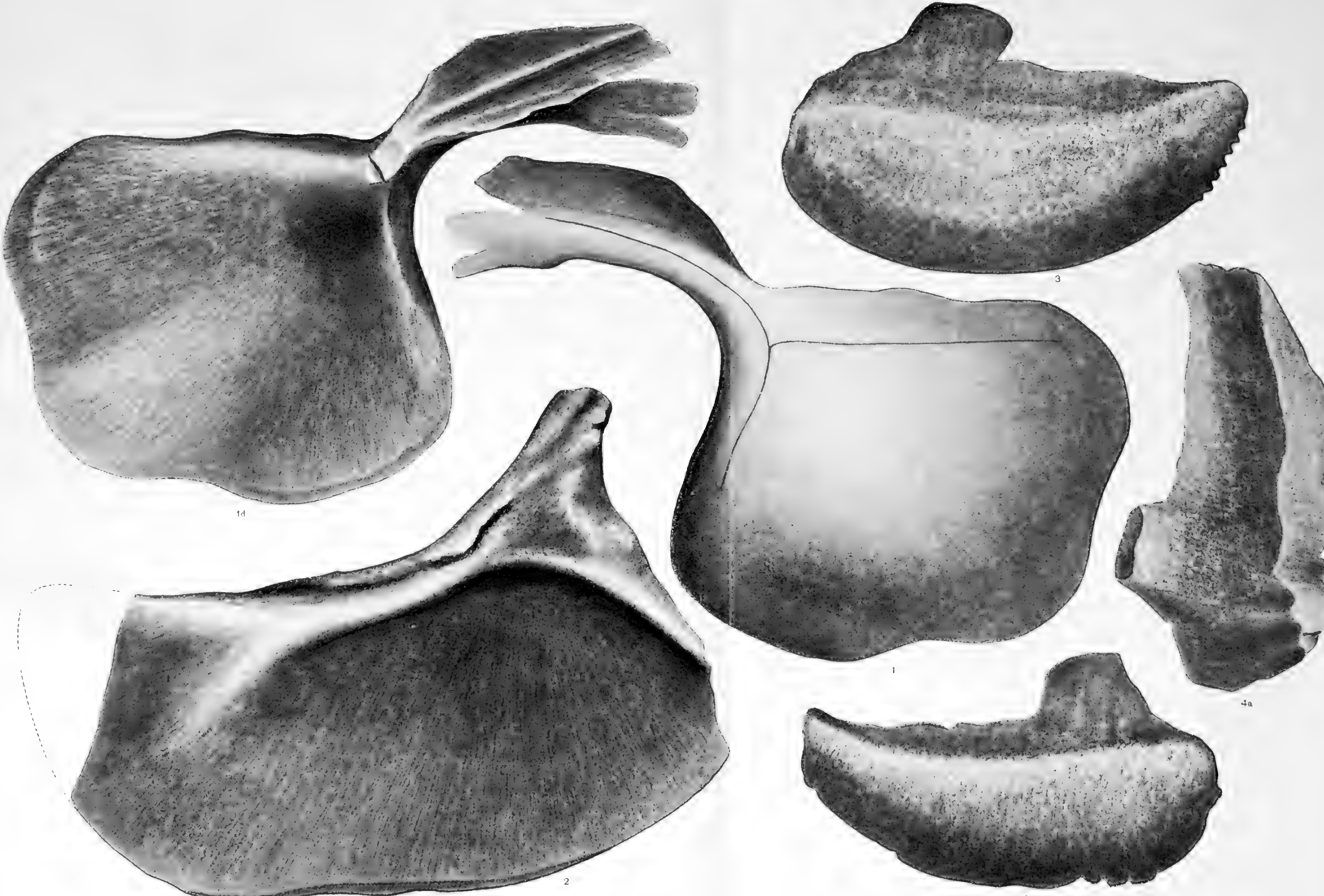
PLATE XLVII.

PLATE XLVII.

DINICHTHYS INTERMEDIUS, Newb. (p. (152).

FIG. 1. Suborbital plate, outside.
1ᵃ. Suborbital plate, inside.
2. Anterior lateral ventral plate, inside.
3. Left maxillary complete, showing teeth on posterior margin.
4. Right maxillary, outside, much worn, showing maturity and average size.
4ᵃ. Right maxillary, inside, showing worn surface.

All natural size. Cleveland shale, Brooklyn, Cuyahoga County, Ohio.



1d 2 1 3 4 4a

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PLATE XLVIII.

PLATE XLVIII.

DINICHTHYS TERRELLI, Newb.

FIG. 1. Clavicle seen from the outside, one-third natural size, linear.
2. Same specimen seen from the inside.
Cleveland shale, Sheffield, Ohio.

DINICHTHYS INTERMEDIUS, Newb. (p. 152).

3. Ventral plate ?
Cleveland shale, Cleveland, Ohio.

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PLATE XLIX.

PLATE XLIX.

ACTINOPHORUS CLARKII, Newb. (p. 175).

FIG. 1. Head, pectoral fins, and anterior portion of body, under side, showing branchiostegal rays, mandibles and teeth, natural size.

1ª. Scales enlarged.

CLADODUS FYLERI, Newb.

2. Tail and posterior portion of body showing myocommata or septa dividing them.
3. Ventral fins, natural size.

Cleveland shale, Cleveland, Ohio.

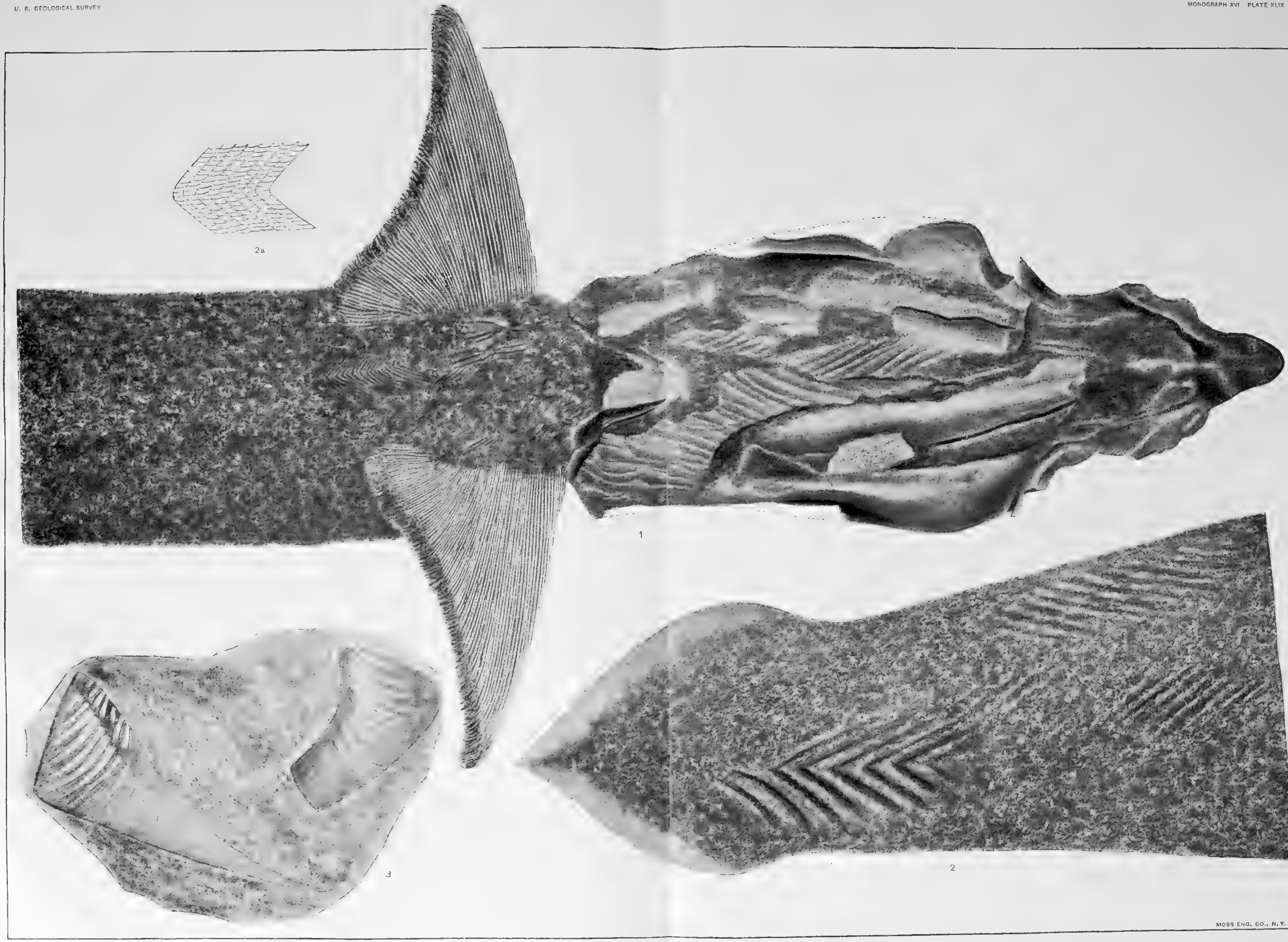
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PLATE L.

PLATE L.

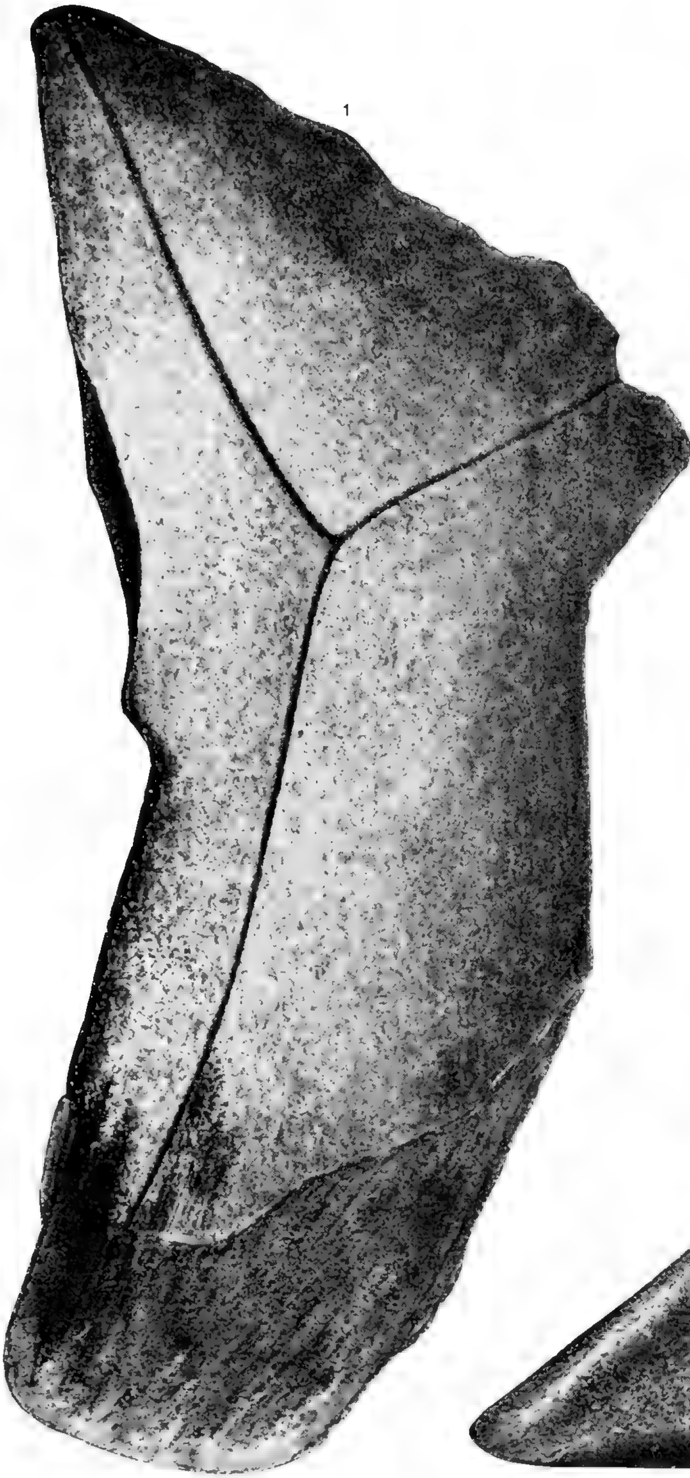
Dinichthys Terrelli, Newb.

Fig. 1. Plate forming posterior lateral angle of cranium, natural size.
Cleveland shale, Sheffield, Ohio.

Dinicthys curtus, Newb. (p. 156).

2. Anterior ventral plate, natural size.
Cleveland shale, Cleveland, Ohio.

1



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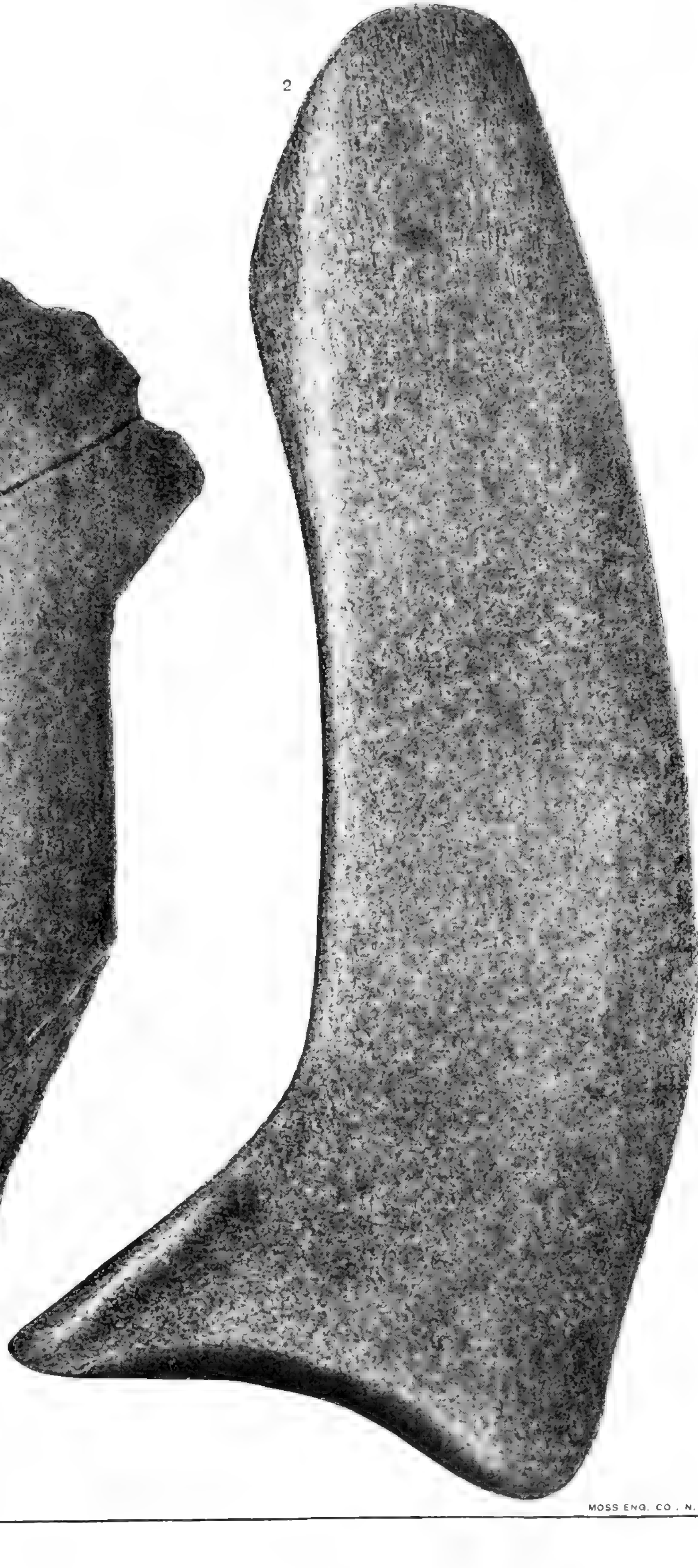

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PLATE LI.

PLATE LI.

DINICHTHYS INTERMEDIUS, Newb. (p. 152).

FIG. 1. Exterior view of cranium, showing suborbital (maxillary) plates in position, one-third natural size, linear.

2. Anterior extremity of head, outside showing nasal, ethmoid, and preorbital plates, one-half natural size.

3. Inside view of Fig. 2, showing nasal (n), preorbital (po), ethmoid (e), and pineal fontanelle in ethmoid plate.

Cleveland shale, Cleveland, Ohio.


3 1/2
1/2 2
1/3 1

PLATE LII.

PLATE LII.

DINICHTHYS INTERMEDIUS, Newb. (p. 152).

FIG. 1. Inside of cranium, showing imperfect supra-scapular plates in place, one-half natural size. Cleveland shale, Cleveland, Ohio.

2. Diagram of head and dorsal plates, viz: *n*, nasal plate; *e*, ethmoid; *po*, preorbital; *pt o*, post-orbital; *so*, suborbital (maxillary?); *pm*, post-maxillary; *m*, marginal; *f*, frontal; *mo*, middle occipital; *eo*, external occipital; *p*, parietal ?; *ss*, supra-scapula; *d*, dorsomedian.

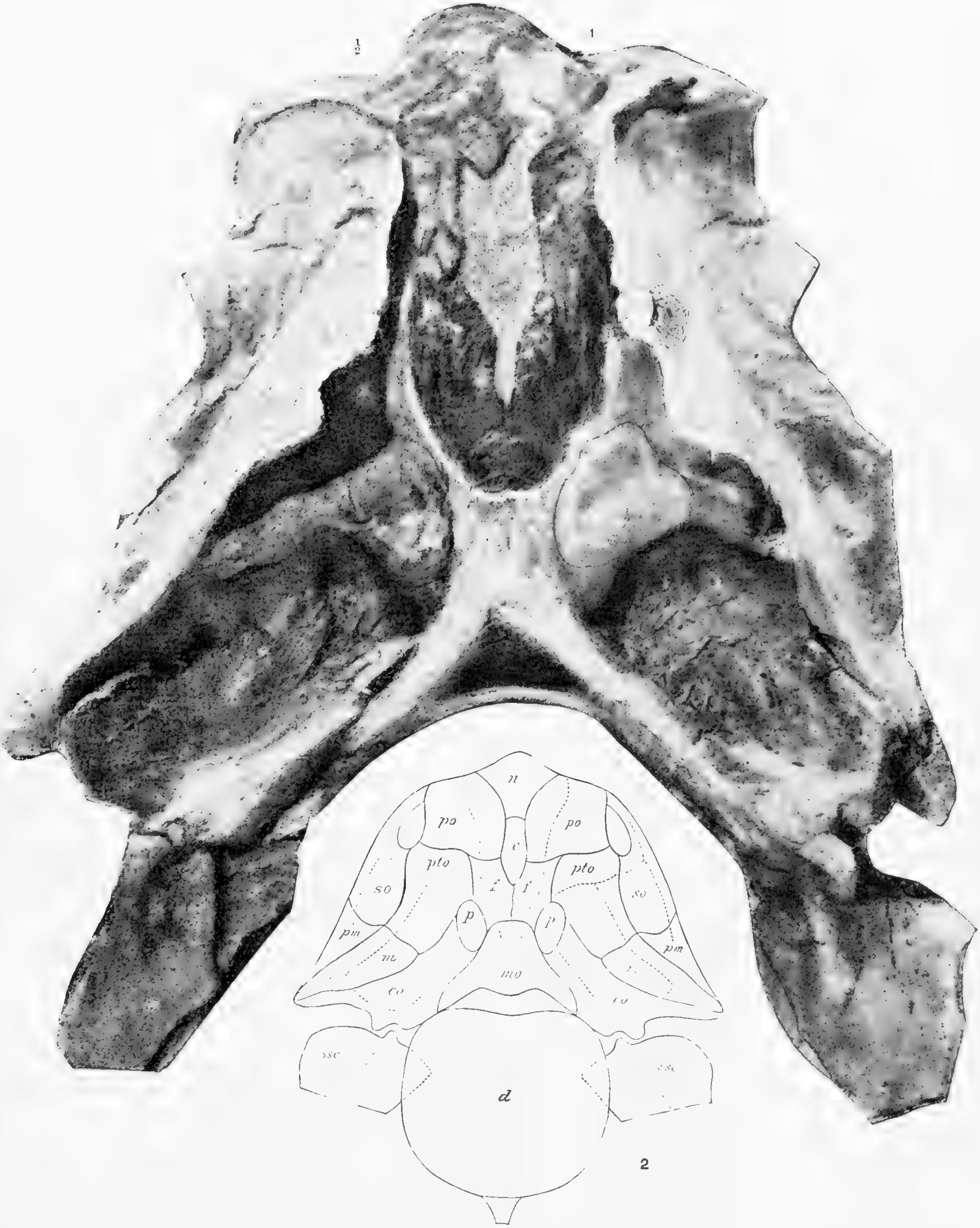

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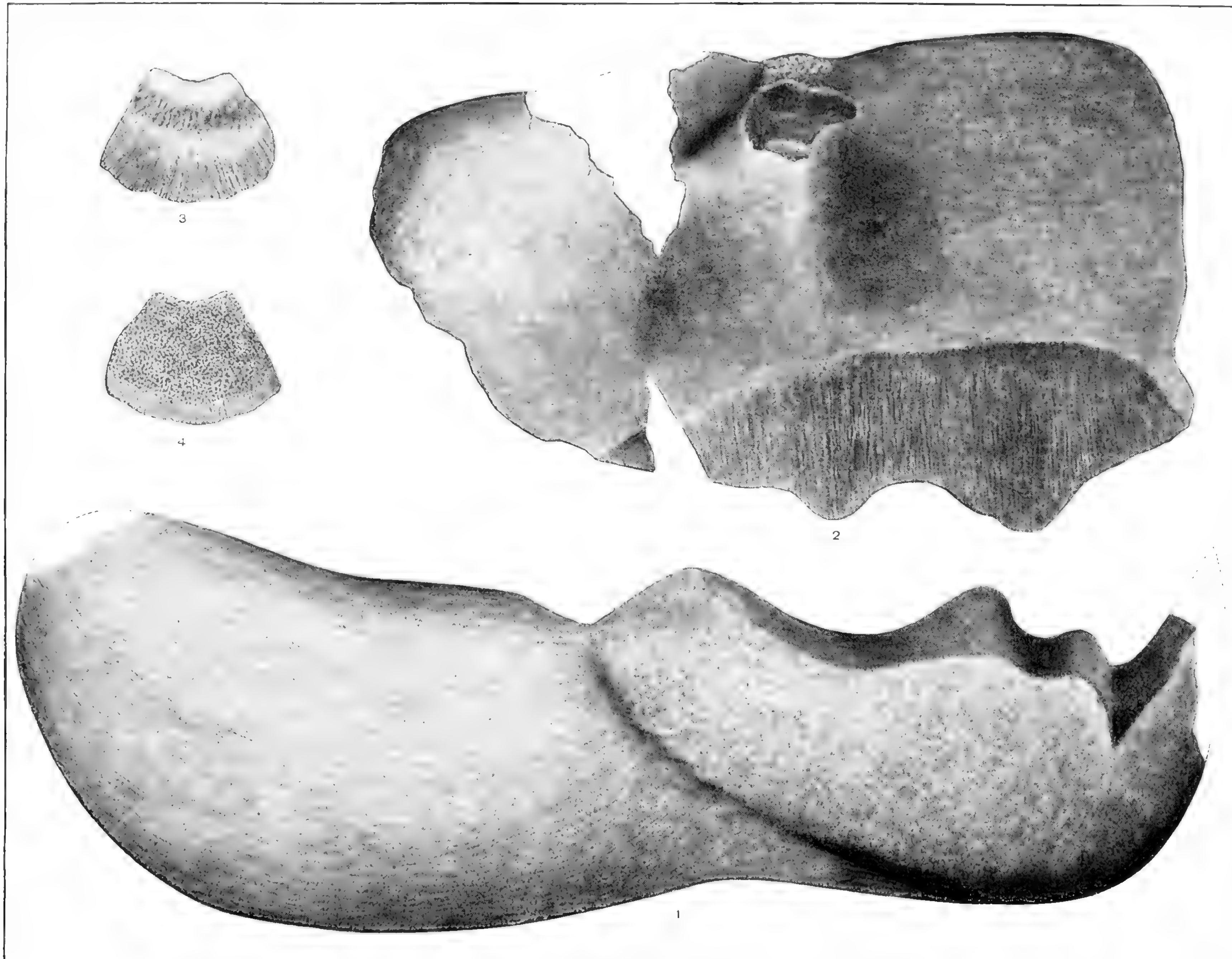
PLATE LIII.

PLATE LIII.

DINICHTHYS CURTUS, Newb. (p. 156).

FIG. 1. Right mandible, outside.
2. Supra-scapular, inside.
3. Sclerotic plate, inside.
4. Sclerotic plate, outside.
All natural size.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INDEX.

[Figures in heavy-faced type indicate pages on which descriptions are given.]